BULLETIN

OF THE

SCIENTIFIC LABORATORIES

OF

DENISON UNIVERSITY

Volume XIV Articles 6-10 Pages 61-188

EDITED BY

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GRANVILLE, OHIO, APRIL, 1909

FOSSILS FROM THE SILURIAN FORMATIONS OF TENNESSEE, INDIANA AND ILLINOIS

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The Silurian formations of Ohio, Indiana, and Tennessee contain a large fauna which awaits elaboration. Preliminary notes on some of the Tennesseean fossils were published in a paper on Silurian and Devonian Limestones of Western Tennessee, in the *Journal of Geology*, in 1903, with the expectation of their further elaboration and illustration. Plates were prepared during the following year, but not published, in the hopes of securing further material in the field. Other duties have intervened, and for some time to come will prevent further study. Under the circumstances it is considered best to publish these plates with their accompanying notes in their present condition, awaiting a future opportunity for more complete study. A part of the figures refer to fossils from Indiana, and a few of the notes include references to forms from Illinois. Several terms of a subgeneric character have been proposed. Whether these terms will commend themselves or not will depend largely upon the question whether future studies will show that they include groups which indicate close affinity and are sufficiently distinct from the types of the genera already described to warrant the separation of these groups from former genera either as subgenera or as independent genera. All the available material has been utilized in an attempt to define these groups. In most cases, the material at hand has not been of such a character as to submit to treatment by chemicals.

Cyrtoceras cinctutus, sp. nov.

(*Plate III, Figs. 37 A, B.*)

Gyroceracone; in the specimen figured the living chamber occupies a length of 30 mm. However, since the margin of the aperture is not distinctly preserved, its original length may have been greater. In a poorly preserved gyroceraconic shell from the same part of the section, with only indistinct traces of costæ, the broken

apical end, about as large as in the specimen here figured, almost touches the dorsal side of the aperture; but on account of its poor state of preservation it cannot be definitely identified with the present species; the distance between the septa is slightly greater. Annular costæ distinct at all stages of growth preserved by the type specimen, deflected toward the apical end; along the sides of the shell, between the dorsal part and the ventro-lateral angle, the curvature of costæ is fairly constant, but at the ventro-lateral angle the costæ are deflected more rapidly toward the apical end of the shell, forming a sinuate curve along the median part of the ventral side. Shell distinctly compressed laterally, the ventro-dorsal diameter of the larger end of the living chamber of the smaller fragment figured being 16.5 mm., and the lateral diameter 12.3. The costæ are more prominent at the ventro-lateral angles, adding to the flattened appearance of the sides and producing also a slightly flattened appearance along the ventral face. Along the median part of the ventral face the costæ form a deeper and more angulate sinus than do the costæ of *Cyrtoceras rigidum*; the shell is narrower, and the greater prominence of the costæ at the ventro-lateral angles is a distinguishing feature. Siphuncle ventrad of the center, about .7 of the distance from the dorsal to the ventral side, poorly preserved, apparently narrow and tubular. Septa 15 in a length of 50 mm. in the type specimen figured, the distance between the septa being greater during the ephebic stage. Internal casts of the shell and such parts of the shell as are preserved show faint transverse striations, about 30 to 35 in a length of 5 mm.; these striations are transverse to the length of the shell and maintain their directions across the costæ. In one weathered specimen there are faint traces of longitudinal striæ, but in all other specimens only transverse striæ are seen.

Osgood bed: Clifton, Tennessee.

Hyolithus cliftonensis, sp. nov.

(*Plate III, Figs. 38 A, B.*)

Length of more complete specimen, 32 mm.; original length possibly 38 mm.; width at the larger end, 12 mm.; width 26 mm. from the larger end, 6 mm.; vertical diameter at right angles to the width at the larger end, 8 mm. Dorsal side strongly convex, but flattened sufficiently on each side of the strongly rounded median

part to produce, in conjunction with the flat ventral side, a subtriangular cross-section. The ventral side, although strongly flattened, is slightly convex, and bears indications, along the median part, of two or three faintly defined linear, longitudinal ridges. A shallow groove, less than a millimeter from the lateral margins, gives these margins a more acute cross-section. The specimens are chiefly in the form of casts of the interiors, or, at least, do not preserve the test well. The larger specimen, however, preserves distinct traces, on the dorsal side, of numerous, close-set, longitudinal striations, alternating in size, Judging from *Hyolithus newsomensis*, these longitudinal striations may have been absent from the ventral side.

Osgood bed: Clifton, Tennessee.

Hyolithus newsomensis.

(*Plate I, Figs. 3 A, B.*)

Length, 22 to 25 mm.; width at larger end, 5.5 mm.; vertical diameter at right angles to the width, 4.2 mm. Dorsal side evenly convex, in cross-section approximately semicircular. Ventral side flattened, the median parts distinctly though moderately concave. Dorsal side striated lengthwise, about 5 or 6 more prominent striæ in a width of 2 mm., the intervals occupied by 4 to 8 finer ones; crossed by transverse striæ which are difficult to see even with a lens. Ventral side crossed by fine transverse striæ and lines of growth, and by almost imperceptible longitudinal striæ. Judging from the transverse striæ, the aperture was not oblique but opened approximately at right angles to the length of the shell.

Waldron bed: Newsom, at the old quarries half a mile south of the station; Swallow bluff, along the upper part of the bluff south of the landing; Iron City, along the top of the bluff at the station; all in Tennessee.

Diaphorostoma cliftonensis, sp. nov.

(*Plate III, Figs. 41 A, B.*)

This species has usually been referred to *Diaphorostoma niagarense*, to which it evidently is closely related. However, it is not identical, and the failure to distinguish between the two species gives them little value in determining the horizons of the rocks in which they are found. *Diaphorostoma niagarense* occurs typically

in the Rochester shales of New York, but is represented also by an almost identical form in the Waldron of Indiana and Tennessee. *Diaphorostoma cliftonensis* occurs typically in the Osgood bed of Tennessee and Indiana, but is represented by almost identical forms in the Clinton.

Diaphorostoma cliftonensis typically is a smaller shell, with a relatively greater height, compared with its width. There are about three and a half volutions, and the last volution never attains the relative width, compared with the height of the shell, which is shown by *Diaphorostoma niagarense*. Height of largest specimen, 20 mm.; width parallel to the aperture, 22 mm.; width perpendicular to this diameter, 17 mm.; height of spire above the aperture, 7 mm.; above the last volution, a little over 2 mm.; width of aperture, 14 mm.; height of aperture, about 15 mm. Shell marked by numerous faint striations transverse to the length of the volutions. There are no striations parallel to the volutions.

Osgood bed: Clifton, Tennessee.

Diaphorostoma brownsportensis.

(*Plate I, Fig. 14.*)

Shell depressed, vertically compressed along the outer margin of the last volution; a groove or depression, usually very distinct, follows the inner edge of the compressed part along the upper side of the volution; a faint depression follows the inner edge of the compressed part along the lower side of the volution. Surface marked by transverse striæ and wrinkles, which are bent back at the compressed edge of the last volution, indicating the presence of a sinus at the aperture having a maximum length of about 4 mm. Volutions about 3, contiguous, the last volution very much flattened near its beginning but less flattened toward the aperture. Resembles *Platyceras sinuatum* as represented by fig. 5, plate 55, vol. iii, of the *New York Paleontology.*[1]

Brownsport bed: glade southwest of Brownsport Furnace, three miles west of Vice landing; north of landing at Cerro Gordo; hill north of Bath Springs; all in Tennessee.

[1] James Hall, *Natural History of New York*, part vi, Paleontology, Vol. III, 1861. Whenever these volumes are referred to later in this paper they will be designated, *New York Paleontology*.

Platyceras pronum, sp. nov.

(*Plate III, Fig. 40.*)

Shell unguiform, with an ovate outline, the beak being twisted sufficiently to make it point toward the right. The shell is striated concentrically, but otherwise is smooth. Length, 28 mm.; width, 18 mm.; vertical elevation, about 11 mm.

Osgood bed: Clifton, Tennessee.

Pterinea brisa, Hall.

(*Plate IV, Fig. 61.*)

Pterinea brisa was described by Hall in the *Twentieth Regents Report* of the State Cabinet of Natural History of New York. The type was obtained at Bridgeport, Illinois. This is an entirely different species from that identified as *Pterinea brisa* from the Waldron bed, Waldron, Indiana. Only a single specimen of *Pterinea brisa* was found in the Waldson bed at Newsom, Tennessee. This was a left valve. It has the following characteristics.

Length of the umbonal ridge or general body of the shell, from the beak to the posterior end of the ridge, 20 mm. The posterior margin of the body makes an angle of about 30° with the hinge line; the anterior margin is nearly vertical. The anterior lobe begins about 9 mm. beneath the beak and extends forward about 5 mm. from the center of the beak. The extremity of the posterior lobe, along the hinge line, is about 18 mm. from the beak; the inner edge of the sinuous curve is about 16 mm. Radiating plications are numerous and sharply defined along the umbonal ridge or general body of the shell. At a distance of 11 mm. from the beak, there are 13 to 15 striations in a width of 5 mm. anteriorly, becoming less frequent and less distinct on the posterior lobe, and reduced to mere crenulations or nearly obsolete on the anterior lobe. Concentric lines of growth rise as sharp narrow laminæ, approximately equidistant on the same parts of the shell, about 12 in a length of 5 mm. at a distance of 10 mm. from the beak. These concentric striæ become more distant toward the posterior lobe of the shell, and closely crowded together on the anterior lobe. While the radiating striæ become stronger toward the anterior edge of the concentric striæ or lamellæ, they are not produced into fimbriæ.

The conspicuous features of this shell compared with the species described from Waldron are as follows. The radiating and concentric striæ are more numerous, and without fimbriæ. The anterior lobe is longer; its upper edge is more nearly parallel to the hinge margin; the sinuosity limiting it from the general body of the shell, originates farther from the beak. The posterior lobe is more extended along the hinge line. The anterior outline of the shell forms a much sharper angle with the hinge line, and the anterior height of the shell, in consequence, is less.

Waldron bed: Newsom, Tennessee.

Pterinea newsomensis, sp. nov.

(*Plate IV, Figs. 59 A, B.*)

Compared with *Pterinea brisa*, from the Niagaran of Illinois, the species described as *Pterinea brisa* from the Waldron bed of Indiana differs considerably. The relative height of the shell is much greater; the anterior outline of the shell forms a smaller angle with the hinge line; the anterior lobe extends a shorter distance from the beak, both anteriorly and vertically; the posterior lobe is less extended along the hinge line and the sinuosity along its posterior margin is less. Both the radiating and concentric striations are less numerous on the left valve, and the concentric striæ or lamellæ are more or less fimbriated where crossed by the radiating striæ, the so-called fimbriæ consisting chiefly of short denticulate projections, the margins of which are sharply turned upward. The shell attains a larger size than in the case of typical *Pterinea brisa*. The right valve is smaller, nearly flat, except toward the beak, where it is only slightly convex. Its surface is comparatively smooth along the main body of the shell, being marked only by rather distant, low striæ, which become indistinct toward the beak. The posterior lobe is marked by rather numerous sharp concentric striæ, crossed by fairly distinct radiating striæ.

Height of one specimen, 26 mm.; length along the hinge line from the anterior edge of the anterior lobe to the tip of the posterior lobe, 29 mm. The sinuous outline limiting the anterior lobe begins 6 mm. from the beak, and the extension of this lobe anterior to the general body of the shell is about 2.5 mm. Radiating striæ about 4.5 in a width of 5 mm. at a distance of 25 mm. from the beak.

Waldron bed: Newsom, Tennessee.

Pterinea nervata, sp. nov.

(*Plate IV, Fig. 60.*)

A third species of *Pterinea* found at Newsom, Tennessee, is in some respects intermediate between *Pterinea brisa* and *Pterinea newsomensis*. Its left valve is marked by radiating striæ, but these are less sharply defined than in *Pterinea brisa*, and are much less numerous. The concentric lamellæ show the fimbriate denticulations, but these are conspicuous only along the less elevated parts of the general body of the shell, where the shell is less worn. In general outline this species approaches *Pterinea newsomensis*, of which it may be regarded as a variety. However, in the case of *Pterina nervata*, when the shell is more or less worn, the general body of the left valve is seen to be covered by radiating striations of various size. The more prominent striæ number about four in a width of 5 mm., the intermediate spaces being occupied by 3 to 5 much finer striæ, visible under a lens. The species is characterized by the more distant radiating striæ, between which are a number of much finer striæ. In size, this shell equals *Pterinea newsomensis*.

Waldron bed: Newsom, Tennessee.

Rhombopteria (Newsomella) ulrichi, sp. nov.

(*Plate IV, Figs. 62 A, B.*)

In surface ornamentation this shell is closely allied to *Rhombopteria mira*, described by Barrande from the Silurian limestone of Bohemia. In our shell, however, it is the right valve which is convex and which carries the characteristic ornamentation. This consists of two systems of striations, more or less radiating, crossing each other at an angle of about 30°. In addition to this there are strong lamellose concentric lines of growth, rather distant from each other, the free edges of these lamellæ being sometimes about a millimeter in width. In one shell, the distance from the beak to the posterior end of the hinge line is 21 mm. The outline of the posterior lobe is slightly concave and makes an angle of about 45° with the hinge line. The height of the shell at the posterior extremity of the hinge line is almost 21 mm. The height where the sinuous outline of the anterior lobe begins is about 13.5. The upper part of the outline of the anterior lobe makes an angle of about 60° with the hinge line. The crossing of the

two systems of striations usually is seen best along the umbonal ridge. No left valves have been found attached to the right valves, but the left valves are believed to be less convex, with strong and distant lamellose lines of growth, similar to those on the right valves, but with radiating striations difficult to recognize even under an ordinary lens. Named in honor of E. O. Ulrich.

Waldron bed: Newsom, Tennessee.

In *Rhombopteria mira*, the type of the genus *Rhombopteria*, the straight hinge line is continued both anterior and posterior to the beak; the left valve is more convex and displays the cross-striations. With this species *Rhombopteria clathrata*, described by Weller from the Coeymans limestone of New Jersey, is congeneric. *Rhombopteria ulrichi* and *Rhombopteria revoluta* differ in the absence of the anterior projection of the straight hinge line, and in the reversal of the valves, the right valve being the more convex one and possessing the conspicuous cross-striations. If these species possess teeth, cardinal or lateral, no trace of them has been found in the specimens at hand. Posterior to the beak, the hinge area of the right valve is thickened for about half the length of the hinge line, and against this thickened area the hinge margin of the left valve rests. The term *Newsomella* is here introduced to distinguish these shells from those typified by *Rhombopteria mira.*

Rhombopteria (Newsomella) revoluta, Winchell and Marcy.

(*Plate IV, Figs. 63 A, B, C.*)

Specimens either identical with *Rhombopteria revoluta*, described by Winchell and Marcy from the Niagaran rocks of Bridgeport, Illinois, or closely related to this species, occur in the Waldron bed, at Newsom, Tennessee. The radiating striæ are much coarser; 12 to 14 striæ occupy a width of 5 mm. at a distance of 10 mm. from the beak. The striations on the posterior wing diverge strongly from those on the anterior part of the body, and along the umbonal ridge, on the posterior side of the body, the two systems of striæ cross. Cross striations are present also on the anterior lobe, only the right valve possessing these radiating striations. The striations on the posterior wing meet the hinge margin at angles of about 30° to 45°. The left valves are less convex, often nearly flat, and are marked by prominent, and rather distant lamellose concentric lines of growth. Between the latter, only

faint concentric striations are visible under a lens. This species is distinctly smaller than *Rhombopteria ulrichi*. The largest specimens do not exceed 22 mm. in length when measured along the umbonal ridge. Considering the small size of the shell, the longitudinal striations of the right valve are very conspicuous.

An examination of the cast of the type of *Rhombopteria revoluta* does not reveal specific differences between this type and the Newsom specimens, but the type is an imperfect exterior cast of the right valve only. In the Newsom specimens the shallow depression limiting the anterior lobe from the body of the shell appears more distinct, the resulting concavity of outline between this lobe and the body is more readily discernible, and the radiating striæ meet the hinge line of the posterior wing at a greater angle. If these features should prove to be fairly constant differences, when more is known of the Bridgeport species, the Newsom specimens might be called *Rhombopteria divaricata*.

Waldron bed: Newsom, Tennessee.

Conchidium legoensis.

(*Plate II, Figs. 36 A, B.*)

Closely related to *C. crassiplica*, but the shell is smaller, the plications are angular rather than rounded anteriorly, and there are 11 to 14 radiating plications, none of them bifurcating anteriorly. Length 29 to 31 mm., width 20 to 24 mm., thickness 16 to 17 mm. Brachial valve depressed along its entire length. Beak of the pedicel valve erect, apex of brachial valve concealed, sides of shell distinctly flattened posterior to the middle.

Brownsport bed: northeast of Lego on Short creek, 300 yards southeast of W. E. Ashley and P. Denman, along hillside south of the valley, Tennessee.

Conchidium lindenensis.

(*Plate II, Figs. 35 A, B.*)

In form of shell and closeness of radiating plications most nearly related to *C. colletti*, but the shell is smaller, there are only 19 radiating plications in the entire width of the shell at a distance of 30 mm. from the beak where *C. colletti* would show 34 plications; moreover, the shell is narrower, and does not possess the frequent lines of growth. Length of largest specimen, 50 mm.

Brownsport bed: east of William Goodwin on Coon creek, two and two-tenths miles east of Linden, near base of exposures on hill side, Tennessee.

Gypidula simplex, sp. nov.

(Plate III, Figs. 51 A, B.)

Shell small, smooth, plicated near the anterior edge. On the pedicel valve two low plications, 3 mm. apart in a shell having a width of about 21 mm., rise sufficiently to foim a low median fold along the anterior third of the valve. On the anterior third of the brachial valve there is a corresponding broad shallow sinus, with a low median plication. There may be an additional smaller plication along the median line of the pedicel valve, and the median plication of the brachial valve may be divided by a narrow furrow into two plications. This shell probably is closely related to *Gypidula angulata*, Weller.

Waldron bed: Newsom, Tennessee.

Gypidula roemeri, Hall and Clarke.

(Plate III, Fig. 51 C.)

The shell figured here is intermediate between *Gypidula simplex* and typical *Gypidula roemeri*.

Waldron bend: Newsom, Tennessee.

Platymerella manniensis, sp. nov.

(Plate I, Figs. 1 A, B, C, D.)

Elongate, equally biconvex pentameroid; not galeatiform, pedicel valve not overarching, and without distinct fold or sinus; without distinct cardinal area. The beaks of the pedicel and brachial valves are practically in contact with one another, so that the delthyrium can not be seen; the beak of the pedicel valve rises slightly higher than that of the brachial valve. The dental plates of the pedicel valve are united so as to form a spondylium supported by a median septum; this septum appears to be supported along its entire length by the interior of the shell, but it is very short, about 6 mm.; the spondylium is small and appears to be confined to the immediate vicinity of the beak. Cross-sections of the shell at the beak show crural plates, moderately convergent,

extending toward the inner surface of the brachial valve, but in no case has it been possible to demonstrate that these plates reach the brachial valve and foim a spondylium.

Shell apparently very thin except at the beak. Exterior marked by low, broad, and often rather indistinct radiating plications, which bifurcate in an irregular manner. In some specimens the median part of the pedicel valve is separated from the lateral parts of the shell by very slight depressions, while the median part of the brachial valve rises almost imperceptibly above the general convexity of the shell. Near the beak, the radiating plications are usually very indistinct.

Form oblong. Length of one specimen, 35 mm.; width, 28 mm.; thickness, 16 mm.

This species does not fit well into any of the divisions established for the pentameroids. It may be an ancestral form in which the spondylia are not yet strongly developed. Its affinities can not be determined more closely until the interior is better known. It is too flat for a *Pentamerella*. The absence of a straight hinge margin is characteristic. The term *Platymerella* is suggested.

Clinton bed: at foot of cliff north of railroad bridge northwest of Riverside, two miles north of Mannie, Tenn.; Cedar Point, one mile north of station at Iron City, at top of ferruginous bed, along the railroad to Pinckney, Tennessee.

? Stricklandinia dichotoma.

(*Plate I, Figs. 2 A, B.*)

Generic affinities uncertain, the interior being unknown; may be one of the *Orthidæ*, but the surface ornamentation resembles that of *Stricklandinia castellana.* Hinge line straight, delthyrium open. Valve moderately convex, 23 mm. long, 30 mm. wide, posterior half of the shell marked by about 20 radiating plications, all of which, except those nearer the posterolateral angles, branch once dichotomously on the anterior half of the shell. Plications crossed by fine concentric striæ which may escape attention if not well preserved.

Clinton bed: at Riverside and Iron City, associated with *Platymerella manniensis;* also in the Clinton at the landing at Clifton, Tennessee.

Scenidium bassleri, sp. nov.

(*Plate IV, Figs. 68 A, B.*)

Shell small, with four or five plications on each side of the median depression in the brachial valve, occasionally with two additional narrow plications on the sides of this depression anteriorly, and sometimes with a narrow intercalated plication even in the space between the first and second conspicuous plications, counting from the depression outward. The median plication of the pedicel valve is distinctly elevated. From this the shell slopes convexly toward the margins of the shell. There are four or five lateral plications on each side, and also occasionally several narrow intercalated plications, near the median parts of the shell. The characteristic features of this species are the small number of plications and the presence of very distinct concentric striæ, rather distant from each other, considering the size of the shell. Width, 5.3 mm.; length, 4 mm.; depth, 2.2 mm. Named in honor of Mr. Ray S. Bassler.

Waldron bed: Newsom, Tennessee.

Rhipidomella lenticularis.

(*Plate II, Figs. 28 A, B.*)

Largest specimen 28 mm. long, 36 mm. wide. Valves moderately convex, the greatest convexity apparently posterior to the center of the shell. Form subcircular, striæ about 160, about 12 to 14 in a width of 5 mm. The hinge line has a length of about 18 to 20 mm., the postero-lateral outline is rounded. Evidently related to *Rhipidomella circulus*, but with more numerous and finer radiating striæ.

Brownsport bed: glade southwest of Brownsport Furnace, three miles west of Vice landing, Tennessee.

Rhipidomella saffordi.

(*Plate I, Figs. 17 A, B, C.*)

A very small species; length, 8 mm.; width, 9 mm.; thickness, scarcely 4 mm. Brachial valve with a median depression which, considering the size of the species, is deep and broad. Pedicel valve evenly convex. Radiating striæ about 6 in a width of 2 mm.

Brownsport bed: in massive limestone near top of Brownsport

bed northeast of stables on Gant place, two miles northeast of Martins mills; Pegram bridge; Bath Springs; east of George Wilson, seven and one-half miles east of Savannah; all in Tennessee.

Rhipidomella newsomensis, sp. nov.

(*Plate IV, Figs. 72 A, B.*)

Among the specimens of *Rhipidomella* found in the Waldron bed, both in Tennessee and in Indiana, there is a small, strongly convex form, apparently mature, which may be distinct from *Rhipidomella hybrida*, as usually identified in the same beds. One of the largest of these specimens is 10.5 mm. long, of almost exactly the same width, being slightly wider, and its depth is 7 mm. Except in their smaller size, and mature appearance at this size, these shells do not differ from the associated specimens referred to *Rhipidomella hybrida*.

Waldron bed: Newsom, Tennessee. Hartsville, Waldron, and at the George Wright locality in Shelby county, Indiana.

Orthostrophia newsomensis, sp. nov.

(*Plate IV, Fig. 64.*)

Ventral valve moderately convex, with a wide depression along the median part toward the anterior margin of the shell. The radiate striation of the shell resembles that of *Orthostrophia halli*, judging from fig. 22, plate VA, volume viii, part i, of the *New York Paleontology*, but the individual at hand is distorted inequilaterally. At earlier stages of growth it was much more extended along the hinge line than *Orthostrophia halli* and even at maturity it is a relatively wider shell. Most of the radiating striæ branch once or twice before reaching the margin of the shell. Muscular cavity of pedicel valve small; the anterior margin only 6 mm. from the beak, considerably elevated above the inner surface of the valve, bordered laterally by the dental lamellæ and their anterior extension at the base. The greater part of the base of the muscular area is formed by a moderately concave platform separated on each side from the base of the dental plates by a narrow groove; the diductor muscular impressions are apparently much narrower than in *Orthostrophia strophomenoides*. Ovarian impressions remarkably distinct, extending about 7 mm. anterior to the hinge line and 6

mm. laterally from the muscular area; with linear dendritic ovarian striæ. Vascular markings in the form of deep grooves with few branches excepting near the anterior margin of the shell.

Waldron bed: Newsom, Tennessee.

Orthostrophia dixoni, sp. nov.

(*Plate IV, Fig. 65.*)

Pedicel valve slightly convex at the beak, flattened or slightly reversed in curvature anteriorly, but it is possible that this anterior flattening of the shell is due partly to crushing. The radiate striation of the shell is rather coarse and resembles that of an orthoid rather than that of a strophomenoid shell. There are about 6 or 7 rather broad striæ in a width of 5 mm., and these are crossed by concentric striæ and lines of growth which resemble those of an orthoid shell. Muscular area of the pedicel valve very small and remarkably deep, the base of the dental plates uniting with the curved anterior edge of the muscular area in such a manner as to produce a border sharply and considerably raised above the inner surface of the valve. The median part of the area is occupied by a low median elevation bordered on each side by a lower lateral elevation, representing the position of the adductor impressions, and occupying about one-third of the width of the area. Length of muscular area, 5 mm.; width, 6 mm. No evidence of ovarian or vascular markings. Delthyrium wide, covered by a small deltidium at the apex.

Brownsport bed: glade southwest of Dixon Spring, Tennessee.

Orthis flabellites.

(*Plate III, Fig. 43.*)

Orthis flabellites is the name suggested for the specimen represented by fig. 6, on plate 52, of volume ii, *New York Paleontology*. This is the species which occurs in the Rochester shale in New York. The species is figured also in figs. 37 to 41 on plate v of volume viii, *New York Paleontology*.

In the list of fossils from the Niagara limestones of Wisconsin, Illinois and Iowa, published in the *Twentieth Annual Report* on the State Cabinet of Natural History of New York, on p. 397, the name *Orthis flabellites* is used evidently for the northwestern form belonging to the group typified by *Orthis flabellites*. Exactly what

western form was termed *Orthis flabellites* in this list is unknown. In volume viii, *New York Paleontology*, on plate 84, Hall and Clarke figured *Orthis flabellites-spania* from the Niagara dolomites near Milwaukee, Wisconsin.

Typical *Orthis flabellites* occurs also in the Osgood bed of Indiana, from which the following description is drawn up. It is characterized by the presence of 28 to 30 simple radiating plications, separated by deep narrow grooves. Specimens with 25 to 27 plications are not rare. The brachial valve is evenly convex, having a depth of 4 to 5 mm. in shells 21 mm. in length. The convexity of the pedicel valve depends on the height of the hinge area which varies from 3.5 to 6 mm., averaging at about 4 mm. From the beak of the pedicel valve the shell slopes with a very slight convexity toward the anterior and lateral edges of the shell, but owing to the height of the hinge area, this results in giving the valve a distinctly convex form, with the point of greatest elevation at or near the beak. The hinge area of the pedicel valve forms an angle of about 60° to 65° with the plane dividing the valves. The hinge area of the brachial valve forms an angle usually of 5° or 10°, rarely of 30°. The muscular scar of the pedicel valve is of an obovate form, the sides being distinctly outlined, and converging anteriorly; the anterior termination of the muscular scar, however, usually is indistinctly outlined. When distinctly outlined anteriorly, the outline is seen to be reëntrant at the anterior margins of the diductor scars, so that the anterior margin of the adductor scars lies at the rear of this angle. The adductor scars are linear in form, and about a millimeter in width, the entire muscular area having a width of 5 mm.

Osgood bed: New Marion, Osgood, Big creek, Nebraska, in Indiana.

Orthis flabellites-militaris, var. nov.

The large form of *Orthis flabellites* found in the Clinton at the Soldiers' Home, near Dayton, Ohio, and represented by figs. 12a and 12b on plate xiii, vol. 1, of this *Bulletin*, differs chiefly in having only 20 to 24 plications, and in having a broad shallow median depression near the beak of the brachial valve, as well as may be determined from the specimens split out of the limestone. The pedicel valve is strongly convex, especially toward the beak which is distinctly incurved.

Clinton bed: at Soldiers' Home, near Dayton, Ohio.

Orthis interplicata, sp. nov.

(*Plate III, Fig. 44.*)

This form differs only in the greater number of radiating plications, a part of them being intercalated between the primary plications. In the specimen figured there are about 21 primary plications, counting all of those initiating at the beak or along the cardinal margin. In addition to these, about 19 secondary plications are added, those near the median line being added within 3 mm. of the beak, and those along the side within 5 mm. of the beak. Traces of the beginnings of several additional plications are found near the anterior edge. The interior of the brachial valve is closely similar to that of typical *Orthis flabellites.* The convexity of the valve is moderate, as in the less convex valves of *Orthis flabellites.*

Osgood bed: New Marion, Indiana.

Orthis nettelrothi, sp. nov.

The shell figured by Henry Nettelroth in *Kentucky Fossil Shells of the Silurian and Devonian Rocks*, on plate xxxiv as *Orthis flabellum*, also has intercalated plications, but it is a larger, more coarsely plicated shell from a higher horizon.

Louisville bed: from the upper part of the Louisville bed, at the Beargrass quarries, east of Louisville, Kentucky.

Hebertella (Schizonema) fissistriata, sp. nov.

(*Plate III, Figs. 45 A, B.*)

Brachial valve moderately convex, with a very shallow median depression. Cardinal area of medium height, forming an angle of about 5° with the general plane of the shell. Cardinal process formed by a thin vertical plate of moderate elevation; in addition to this plate two narrow striæ occupy the space between the crural plates, diverging from the cardinal process at an angle of about 25° to 30°. These are well developed in two specimens, but whether a constant feature of this species can not be determined at present. From the space between the crural plates, a broad median elevation extends forward to the center of the valve. The posterior adductor impressions may be traced, but the anterior impressions are very indistinct.

Pedicel valve a little more convex than the brachial valve, the cardinal area of moderate height, forming an angle of about 30° with the general plane of the brachial valve. Delthyrium wide, the sides diverging at an angle of 65°. Muscular impressions small, the anterior margin about 6 mm. from the beak; the lateral margins converging anteriorly; outline reëntrant in front of the linear adductor impressions, as in typical specimens of *Orthis flabellites*.

Radiating striations angular, increasing by intercalations at various distances from the beak. About 13 to 15 striæ originate at or very near to the beak; 28 striæ originate at least within 3 mm. of the beak, so that about 13 to 15 striæ must have been intercalated between the more primary striæ within a short distance of the beak. Additional striæ are added about 9 mm. from the beak, and along the margins of the shell a total of 60 striations may be counted. While the striæ originate in a fasciculate manner they are not sufficiently different in size, and the primary striæ are not sufficiently prominent to make the fasciculation at all conspicuous, differing in this respect from *Orthis fasciata*, Hall. Concentric striæ, if present, were not noticed on the specimens at hand.

Osgood bed: New Marion, Indiana.

The shell is not considerably thickened beneath the muscular area of the pedicel valve, as in *Orthostrophia strophomenoides*, nor are the vascular markings conspicuous. The muscular area of the pedicel valve is not conspicuously smaller than in shells of this size belonging to typical *Orthis*. For the group of shells having the structure of *Hebertella fissistriata*, with numerous intercalated striæ, with the brachial valve not exceeding the pedicel valve in convexity, but externally resembling *Hebertella*, the term *Schizonema* is suggested. This term should include apparently also *Orthis fasciata*, Hall, which is not a true *Orthostrophia*, and possibly also *Orthis fissiplica*, Roemer.

Hebertella (**Schizonema**) **fasciata,** Hall.

(*Plate IV, Fig. 71.*)

Among the specimens found in the Osgood bed, at New Marion, in Indiana, is one which closely resembles the description given of *Orthis fasciata* from the Rochester bed of New York. The postero-lateral angles are broken off so that the extension of the

hinge line beyond the general width of the shell can not be verified. The fasciation, however, is distinct, especially on the pedicel valve. About 10 striations begin at or very near to the beak, and between these an approximately equal number is intercalated almost immediately, so that about 18 fairly prominent striæ extend from near the beak to the margins of the shell. These striæ have a tendency to occur in pairs, as though resulting from the division of the more primary striæ. About 7 mm. from the beak other striæ are intercalated, and anterior to this there may be a few additional striæ, so that the anterior and lateral parts of the shell are marked apparently by fascicles of striæ, the fascicles consisting of three or four striæ near the median parts of the shell, the primary striation of each fascicle being considerably more conspicuous, as in *Plectorthis fissicosta.* The fascicles have a tendency to occur in pairs.

Length of shell, 15 mm.; width across the middle, 19 mm.; depth of the entire shell, 6 mm. The valves are nearly subequal in convexity.

Osgood bed: New Marion, Indiana.

Hebertella (Schizonema) nisis, Hall.

This species is evidently closely related to *Hebertella fissiplica,* it shows about the same range of variation in the coarseness and frequency of the radiating striæ and in the curvature from front to rear of the pedicel valve. It has the median depression of the brachial valve; the high cardinal area, inclined strongly backward, of the pedicel valve; the pedicel valve is conspicuously more convex and deeper than the brachial valve; the delthyrium is narrow.

It differs from *Hebertella fissiplica* in the greater convexity of the brachial valve and the greater height of the cardinal area of the pedicel valve. This area is more incurved near the beak in one of the specimens figured by Hall than in any specimens of *Hebertella fissiplica* so far seen. See figs. 4 to 8 on plate 9 of the Twenty-seventh Report on the New York State Cabinet.

Louisville bed: in the upper strata exposed in the quarries along Beargrass creek east of Louisville, Kentucky.

Hebertella (Schizonema) fissiplica, Roemer.

(*Plate III, Fig. 54.*)

Shell plano-convex. Brachial valve nearly flat or slightly convex with a distinct but shallow median depression similar to that of *Dalmanella jugosa*; cardinal area very narrow, deviating but slightly from the general plane of the valve; cardinal process in form of a thin, simple, vertical plate, as in *Orthis flabellites*. A thickened elevated median ridge extends from the deltidial cavity forward to a point a short distance beyond the center of the valve. Muscular impressions indistinct.

Pedicel valve convex; cardinal area high and flat, but slightly if at all incurved at the beak, forming an angle of about 110° with the general plane of the brachial valve; delthyrium narrow as in *Hebertella nisis*. In the specimens from Dixon spring, the shell is but slightly curved along the median line, from the beak to the anterior margin. In the larger specimens from Clifton, the curvature corresponds more nearly to that of *Hebertella nisis*. In general the shell slopes strongly from the beak to the lateral and anterior margins. Muscular impressions small and rounded, elevated at the margin slightly above the interior of the valve; margin slightly incurved anterior to the adductor muscle impressions; the latter are linear and occupy about one-fifth of the entire width of the muscular impressions. Size of muscular area small, corresponding to that of *Orthis* rather than that of *Hebertella*. Interior of valves radiately grooved along the border as in typical species of *Orthis*.

Radiating striæ about 22 within 4 mm. of the beak, increasing to about 45 at the margin, about 5 to 7 striæ occupying a width of 5 mm. At their origin the newer striæ are much less conspicuous than the older striæ, usually originating near the latter although sometimes inserted near the middle of the spaces between the older striæ. The older striæ are usually more conspicuous, resulting in an alternation of larger and smaller striæ or in a more or less fasciculate arrangement. Radiating striæ crossed by numerous fine, sharp concentric lines, usually well preserved between the striæ.

In fig. 5a, plate 5, of Roemer's monograph on the *Silurian Fauna of Western Tennessee*, the posterior margin along the hinge area is drawn too concave to the right and left of the beak. In fig.

5b, the reversal of curvature is due to crushing, common except in silicified shells; the cardinal area of the brachial valve should be much higher, and the inclination of the cardinal area of both valves is incorrectly indicated. Errors of this nature are shown also by other drawings accompanying this paper.

Brownsport bed: glades southwest of Dixon Spring; Clifton, west of Dr. Evans, west of Hope creek; south of Mr. Phillips, four miles northwest of Martins mills; Bath Springs; Wells creek basin, Tennessee.

Hebertella (Schizonema) celsa, sp. nov.

(*Plate III, Figs. 53 A, B.*)

Brachial valve moderately convex, with a distinct but shallow median depression as in *Dalmanella*. Cardinal area forming an angle of about 150° with the general plane of the valve. Upper margin of cardinal process narrow, projecting slightly beyond the cardinal area, marked by a faint longitudinal groove. Anteriorly the cardinal process is merged in the comparatively high median elevation which divides the muscular area. Crural plates strongly developed, their base continuous with the straight postero-lateral border of the posterior adductor impressions. Anterior margin of the anterior adductor impressions extending slightly beyond the center of the valve. Muscular impressions resembling those of *Hebertella insculpta*.

Cardinal area of the pedicel valve flat, forming almost a right angle with the general plane of the brachial valve, broadly triangular, high at the beak. The type specimen has a width of 16.5 mm., the cardinal area has a length of 13 mm. along the hinge line, and the height of the area is 4.3 mm. The width of the delthyrium is about 2.5 mm. at the widest part, at the apex it appears to possess a rather large apical plate, poorly preserved. Curvature from the beak to the anterior margin of the shell slight, the shell sloping rather evenly but abruptly from the beak to the lateral and anterior margins of the shell.

Radiating striæ rather angular, the newer striæ being implanted among the older so as to produce a fasciculate arrangement; about 8 or 9 striæ in a width of 5 mm. Numerous fine concentric striæ.

Linden bed: above quarry along river north of Perryville, Tennessee.

Chonostrophia lindenensis, sp. nov.

(*Plate III, Fig. 52.*)

Shell with extremely fine, filiform radiating striæ, visible under a lens. Pedicel valve slightly convex near the beak and slightly concave as a whole. Width, 23 mm.; length, 11 mm. The great width of the shell, compared with its length, will distinguish it readily from any species described hitherto.

Linden bed: Pyburn bluff, Tennessee.

Triplecia (Cliftonia) striata, sp. nov.

(*Plate III, Figs. 42 A, B.*)

The external aspect of this species is that of a small *Atrypa*, but the internal structure indicates close relationship to *Triplecia*.

Brachial valve circular in outline; pedicel valve more nearly ovate. Brachial valve strongly convex, raised so as to form a low broad median fold anterior to the middle. The shell starts at the beak with a median groove which is rather conspicuous along the posterior third of the shell. Pedicel valve rather strongly convex posteriorly, but bent downward anteriorly so as to form a broad shallow median depression, not always symmetrical. Radiating striæ rather coarse and distant considering the size of the shell, about 7 to 9 in a width of 5 mm. Concentric striæ probably were distinct on the original shells. Length of the pedicel valve, 13 mm.; width, 13 mm.; depth, almost 3 mm. Length of brachial valve practically the same as that of the pedicel valve, but the depth is almost 6.5 mm.

Interior of brachial valve with a linguliform cardinal process, 1.7 mm. in length, and $\frac{3}{4}$ mm. in width at the hinge line. This process becomes broader anteriorly, and divides near the tip into two short, sharply pointed, divisions. The impressions of two short sharply pointed cruræ are seen in one of the specimens. There is a narrow median striation along the posterior third of the interior, corresponding to the median groove on the exterior. The interior cast of the pedicel valve indicates the presence of a rather high flat hinge area, whose length is about 8 mm. in a shell 13 mm. wide. The height of this area is estimated at almost 2 mm. A conspicuous cavity extended from the interior of the shell along the part enclosed within the beak, and opened by means of a small aperture at the tip of the beak. Teeth supported by short dental

lamellæ which are only 1.5 mm. in length, and are separated anteriorly by a space about 1.4 mm. in width. A sharp striation borders the sides of the aperture leading to the beak.

Clinton bed: south of the old abandoned Cement Mill, south of Clifton, Tennessee.

The type of *Triplecia* is *Triplecia extans*, a smooth shell. From this *Triplecia striata* differs sufficiently in general appearance to warrant the erection at least of a subgeneric term. For the striate species, resembling *Triplecia striata*, the term *Cliftonia* is here suggested. Possibly *Triplecia niagarensis*, Hall and Clarke is congeneric.

? Triplecia (Cliftonia) tenax, sp. nov.

(*Plate III, Fig. 36; Plate IV, Figs. 70 A, B.*)

Shell with the external aspect of a *Hebertella*, but apparently so similar in form to *Triplecia* (*Cliftonia*) *striata*, that these shells are regarded as very closely related, although the interior structure of *Triplecia tenax* is not known. Compared with *Triplecia striata*, *Triplecia tenax* is a larger, broader, and less strongly convex shell. It possesses the low broad median fold on the anterior part of the brachial valve, and the broad, shallow depression along the anterior part of the pedicel valve. The median groove toward the beak of the brachial valve is distinct. The hinge area on the pedicel valve is well defined, but nothing is known about the delthyrium. The radiating striations are distinctly stronger than in *Triplecia striata*, especially in case of the primary striæ. Between 6 and 7 striations are found in a width of 5 mm. Concentric markings indistinct on the considerably exfoliated surface of the shell.

Length, 13.5 mm.; width, 18 mm.; depth, 9 mm. Length of hinge line, 10 mm. Height of hinge area, about 1.6 mm. Convexity of valves approximately equal. Radiating striæ increased by implantation of additional striæ at various distances from the beak, resulting in a fasciculate arrangement.

Osgood bed: Clifton, Tennessee.

Schuchertella roemeri.

(*Plate II, Figs. 27 A, B, C.*)

Shell evidently related to *Orthothetes subplanus* with which it usually is identified, but the shell is smaller, the number of radiating plications is smaller, and the intermediate spaces much broader.

Width, 28 to 30 mm. This is evidently the species identified by Roemer with *Orthothetes subplanus*.

Brownsport bed: glade southwest of Dixon Spring, also at Pegram, Tennessee.

Plectambonites tennesseensis.

(*Plate I, Figs. 5 A, B, C, D, E.*)

Width, 7 to 9 mm.; convexity, 2.2 mm.; pedicel valve with 5 more conspicuous radiating striæ, distinct even near the beak, the intermediate spaces occupied in each case by a single radiating striation which extends only halfway from the margin of the shell toward the beak. Finer radiating striæ practically obsolete. Concentric markings of the shell rather distant, distinct, due to difference in color caused by clay entering the thin spaces left at different stages of growth.

Waldron bed: Iron City, at Cedar Bluff, also at the station; Swallow Bluff; along the river three-quarters of a mile above the landing at Clifton; along the road leading east from New Era; Newsom; all in Tennessee.

Strophonella tenuistriata, sp. nov.

(*Plate II, Figs. 20 B, A.*)

Evidently related to *Strophonella roemeri*, but the shell is smaller, the outline is more semicircular, and the curvature of the shell where it is deflected anteriorly is much more moderate and not at all sufficient to be called geniculate. Width, 31 mm.; length, 20 mm. Brachial valve distinctly concave over the larger part of the flattened area anterior to the beak, reversal of curvature beginning about 10 or 11 mm. anterior to the beak. Pedicel valve distinctly convex for a distance of about 8 mm. anterior to the beak, the remainder following the curvature of the brachial valve. Surface with fine radiating striæ, 5 to 8 more prominent striæ in a width of 5 mm., separated by 3 to 6 finer striæ. Inner surface granulose. This is probably the species identified by Roemer with *Strophonella euglypha*. His specimens were fragmentary, his figures were restored, and the curvature of the shell as indicated by fig. 3c, plate 5, of his work, *Silurische Fauna des westlichen Tennessee*, is probably incorrect at the anterior extremity; if the anterior part, 5 mm. long, were omitted, the figure would be a fair

representation of the curvature of the Tennessee specimens. Our fig. 20 A is taken from a specimen which evidently equaled his fig. 3b in size.

Brownsport bed: on hill side south of road leading east from New Era; also north of landing at Cerro Gordo, Tenn.; and in massive limestone northeast of stables on Gant place northeast of Martins mills, Tennessee.

Strophonella williamsi, described by E. M. Kindle from the Silurian of northern Indiana, appears to be a much more convex species, when viewed from the side of the brachial valve.

Strophonella roemeri.

(*Plate II, Fig. 24.*)

Shell subtrigonal in fully developed specimens, probably more semicircular in young specimens, the subtrigonal form being due chiefly to the greater growth of the shell along the anterior edge and the rapid deflection of the shell antero-laterally. Width at hinge-line 56 mm.; brachial valve distinctly flattened anterior to the beak for a distance of about 18 to 20 mm., slightly concave toward the beak, abruptly deflected anterior to the flattened area, the deflection being greater toward the antero-lateral margin than toward the anterior median parts of the shell. Antero-lateral slopes more or less flattened. From the anterior part of the flattened area to the anterior part of the shell may be a distance in the largest specimens of 37 mm., but usually 34 to 30 mm., or even less. Pedicel valve slightly convex near the beak, following the curvature of the brachial valve. Cardinal margin crenulated for a distance of about 7 mm. on each side of the delthyrium. Muscular area of pedicel valve 13 mm. long, 16 mm. wide, lateral margins thickened and raised abruptly above the inner surface of the valve, open along the median line anteriorly; adductor scars distinctly defined posteriorly by low elevations which begin at the beak and branch within 1 mm. of the same, the two exterior branches defining the postero-lateral margins of the scar, the two inner and much shorter branches defining the inner margins at the posterior extremity. Between the two inner branches arises the narrow median elevation which divides the adductor area. Inner surface granulose, the granules arranged in lines approximately following the exterior ornamentation of the

shell; this granulated area passes behind the muscular area and almost reaches the beak. A profile view of the pedicel valve resembles fig. 4c of plate 23, vol. iii, of the *New York Paleontology*. Surface with radiating striæ, about 7 to 10 more prominent striæ in a width of 10 mm., separated by 4 to 8 finer striæ.

Brownsport bed: glade southwest of Brownsport Furnace, three miles west of Vice landing, Tennessee.

Strophonella prolongata.

(*Plate II, Figs. 23 A, B.*)

Width, 31 mm.; length, 15 mm. Shell broadly sub-semicircular, considerably extended along the hinge line; brachial valve flattened for a distance of 10 or 11 mm. anterior to the hinge line, slightly concave toward the middle of this surface; anterior to the flattened area the shell is deflected almost vertically, producing a profile similar to that of fig. 6c, plate 23, vol. iii, *New York Paleontology*. Pedicel valve slightly convex anterior to the beak, following the curvature of the brachial valve; cardinal line crenulated for a distance of about 3 mm. on each side of the delthyrium; interior showing the character of the striation of the exterior surface distinctly; muscular impressions not distinct, a faint median elevation, and two faint elevations defining the postero-lateral margins of the muscular area. Surface with radiating striæ which are rather coarse and prominent considering the size of the shell, about 18 to 21 in a width of 10 mm. along the anterior margin.

Brownsport bed: glade southwest of Brownsport Furnace, three miles west of Vice landing, Tennessee.

In the massive limestone layer near the top of the Brownsport bed, northeast of the stables on the Gant place, northeast of Martins mills, a specimen is found which shows a strong median depression on each side of which the shell is slightly raised. It is represented by fig. 22 on plate ii, of this paper and evidently resembles *Strophonella geniculata*, fig. 6, plate 23, vol. iii, *New York Paleontology*. The striations are coarser. The specimen is poorly preserved.

Strophonella dixoni, sp. nov.

(*Plate II, Fig. 21.*)

Evidently related to *Strophonella prolongata*, but smaller. Width, 16 mm.; length, 7 mm.; brachial valve flattened and slightly con-

cave anterior to the hinge line, the flattening extending for a distance of almost 6 mm. anterior to the beak; at this point the shell is strongly curved, the anterior part of the shell being deflected almost vertically downward. Pedicel valve following the curvature of the brachial valve. Radiating striæ strong and coarse considering the size of the shell, about 11 in a width of 5 mm. along the anterior margin.

Brownsport bed: glade southwest of Dixon Spring, also at Clifton, Tennessee.

Strophonella ganti, sp. nov.

(*Plate II, Fig. 22.*)

Shell small, about 16 mm. in width along the hinge line, and varying from 8 to 10 mm. in length. Resembling *Strophonella geniculata*, Hall, from the Lower Helderberg, in having a broad median depression along the brachial valve, becoming stronger toward the geniculate border. The striations appear to be rather coarse, as in *Strophonella prolongata*. There is not sufficient material to establish the validity of this form as a species.

Brownsport bed: in the coarse sandy limestone at the base of the Gant layer, forming the upper part of the Brownsport formation, at the A. B. Gant place, and at Martins Mills, Tennessee.

Strophonella laxiplicata.

(*Plate II, Fig. 25.*)

The most perfect specimen appears to be only a young form of this species. The brachial valve is slightly concave, and the pedicel valve is moderately convex anterior to the beak. The reversal in curvature takes place about 11 mm. anterior to the beak. The most characteristic part of the shell is the nature of the radiating striæ. The striæ are rather sharply elevated above the general surface of the shell; and are separated by comparatively wide spaces in which finer intermediate striæ are absent or practically obsolete. Only a small number of striæ, usually less than 10, begin at the beak, and new plications are added usually by intercalation, appearing near the middle of the comparatively wide intermediate spaces. Cardinal area striated vertically. Radiating striæ crossed by fine concentric striæ which are seen only under a lens, chiefly in the spaces between the striæ. Width of type

specimen, 21 mm. At Brownsport Furnace, three miles west of Vice landing, a specimen having the characteristic surface ornamentation of this species, but at least 37 mm. wide, was found.

Brownsport bed: Brownsport Furnace, Tennessee; Cerro Gordo; Bath Springs; east of George Wilson, seven and one-half miles east of Savannah, Tennessee.

Strophonella semifasciata-brownsportensis, var. nov.

(*Plate II, Fig. 26.*)

At Brownsport a single fragment was found of a *Strophonella* in which the spaces between the more prominent striæ are very wide. The finer intermediate striæ usually found are entirely obsolete in this specimen. Between the stronger striæ already mentioned the spaces are either flattened or broadly concave. The striæ tend to become indistinct toward the beak. Although represented only by a small fragment, the specific characters are striking. Its nearest relative is *Strophonella semifasciata*, Hall, from the Waldron bed, of which it may be only a smaller variety.

Brownsport bed: Brownsport, Tennessee.

Stropheodonta (Brachyprion) newsomensis, sp. nov.

(*Plate IV, Fig. 67.*)

Stropheodonta newsomensis is a smaller species than *Stropheodonta profunda* from the Clinton of New York. While occasional specimens are quite strongly convex, the convexity of the greater number is not sufficiently great to warrant the term profound. In the type of *Stropheodonta profunda* the convexity is stated to be three-fourths of an inch, the length of the shell, as determined from the accompanying illustration, being 43 mm., and the width 53 mm. across the middle. A large sized, rather strongly convex, specimen of *Stropheodonta newsomensis* has a length of 33 mm., a width of 36 mm. across the middle and 40 mm. at the hinge, and a depth of about 11 mm. The valves are thin, and the space between them scarcely exceeds 3 mm. nearer the hinge line and 1 mm. anteriorly. The convex ventral valve is marked by fine and rather distant radiating striæ, between which there are sets of three or four still finer striæ. Toward the anterior and lateral margins these striæ become larger and more nearly subequal, or alternately large and small. The larger striæ near the

margin number about 11 in a width of 5 mm. The radiating striæ on the dorsal valve are still finer. The concentric striæ on both valves can be seen only with a lens.

The interior of the pedicel valve shows the crenulations on the cardinal margin for a distance of about 4 mm. from the delthyrium. The muscular area is triangular flabelliform, well defined laterally but not anteriorly. A median ridge divides the posterior part of this area, and near the beak this thickens into a callosity filling the median part of the space between the hinge teeth. From this callosity two short ridges diverge anteriorly, in addition to the median ridge.

The cardinal process of the brachial valve consists of two lobes, slightly over 2 mm. long, diverging at angles of 50° from each other, in a plane at right angles with the shell. Anterior to the cardinal process, the shell is thickened so as to form a subrhomboidal space, anterior to which there are only faint traces of muscular impressions. The posterior parts of the brachial valve, and also of that part of the pedicel valve which lies outside of the muscular area, are marked by coarse granules, becoming more numerous and finer anteriorly. In some shells only the coarser granules are present.

Waldron bed: Newsom, Tennessee.

Meristina maria-roemeri, var. nov.

(*Plate II, Fig. 29 A, B.*)

This species is evidently closely related to *Meristina maria* of the Waldron horizon, but is readily distinguished by its subtrigonal outline, especially when viewed from the side of the pedicel valve. This subtrigonal outline is produced by a straightening of the postero-lateral outline. The strongly sinuous outline of the anterior margins of the valves is normal in this form while in typical forms of *Meristina maria* it usually is less developed. See fig. 12, plate 5, of Roemer's work in the *Silurian Fossils of Western Tennessee.*

Brownsport bed: north of landing at Glenkirk, at mouth of Beech creek; glade southwest of Brownsport Furnace, three miles west of Vice landing; mound glade half a mile west of road, two and one-half miles north of Vice store; Martin's Mills; old Colonel Jim Smith's place, nine miles east of Savannah; bridge two miles west of Pegram; all in Tennessee.

Anoplotheca saffordi.

(*Plate I, Fig. 6.*)

Length, 5 mm.; convexity, 2.8 mm. Pedicel valve strongly convex, with the 3 median radiating plications (the middle one narrower) forming an indistinct elevation, with 4 distinct and one indistinct plication on each side; the beak projecting but slightly beyond that of the brachial valve. Brachial valve concave, especially anteriorly along the shallow median depression; depression occupied by 2 radiating plications placed close together and separated by a short space from the lateral plications of which 4 are distinct and one indistinct.

Brownsport bed; in the massive limestone near the top of the Brownsport exposure, northeast of the stables on the Gant place, northeast of Martins Mills; Bath Springs; east of George Wilson, seven and one-half miles east of Savannah; all in Tennessee. The same species, described as *Anoplotheca congregata*, by E. M. Kindle, occurs in the Kokomo limestone at Logansport, Indiana.

Homœospira schucherti.

(*Plate I, Figs. 10 A, B.*)

Shell broadly ovate; length of one of the type specimens, 11 mm.; width, 10.3 mm.; thickness, 6.8 mm. Both valves with a shallow median groove or depression most distinct anteriorly, usually occupied by one or two plications originating in the groove a short distance anterior to the beak, less distinct than the remainder; about 7 distinct and 1 indistinct radiating plications on each side of the median groove. Length of largest specimen seen, 13 mm.; named in honor of Mr. Charles Schuchert.

Brownsport bed: Brownsport Furnace, Tennessee.

Homœospira schucherti-elongata, var. nov.

(*Plate I, Figs. 9 A, B.*)

Shell smaller, narrower, median groove more distinct, radiating plications usually narrower and closer together, as in fig. 9 B; about 8 distinct plications on each side of the median groove, with one or two less distinct plications within or along the walls of the groove. Shell narrower and more convex from side to side, the beak of the pedicel valve more incurved over that of the brachial

valve. Length, 9 mm.; width, 7.6 mm.; thickness, 6.2 mm., in one specimen . Apparently connected by intermediate forms with *Homœospira schucherti*, although extreme forms are readily distinguished.

Brownsport bed; north of the home of W. N. Davis, Bath Springs, Tennessee, associated with *H. schucherti*.

Homœospira beecheri.

(*Plate I, Figs. 8 A, B.*)

Very small; length, 6.5 mm.; width, 6 mm.; thickness, 3.5 mm. Convexity of shell rather small, form broadly ovate, radiating plications more distinct at the beak than in *H. schucherti*, 6 distinct and 1 indistinct plication on each side of the median groove. Beak of the pedicel valve erect, raised above that of the brachial valve, not strongly infolded. Median groove of brachial valve scarcely larger than that between the plications nearest the groove, occupied by a single very narrow plication which anteriorly divides into 2 very narrow parallel closely set plications very easily overlooked. Median groove of ventral valve broader, occupied by two narrow plications, much narrower than the plications on each side of the median groove, but much more distinct than those occupying the base of the groove in the brachial valve. Named in honor of Mr. Charles Beecher.

Brownsport bed: glade southwest of Brownsport Furnace, west of Vice landing, Tennessee.

Homœospira pisum sp. nov.

(*Plate I, Fig. 7.*)

Shell smaller and more convex than any of the forms described above. Length, 6.3 mm.; width, 5.5 mm.; thickness, 4.5 mm. Lines of growth numerous near the anterior margin; shells evidently mature notwithstanding their small size. Beak of pedicel valve either curving strongly over that of the brachial valve, or lifted considerably above the latter and only moderately overarching the same. Median groove of both valves distinct; 2 very narrow plications occupy the median groove of the brachial valve, while the two plications which are inserted along the median line of the pedicel valve a short distance from the beak almost equal

the other radiating plications in size anteriorly, and are but slightly depressed below the level of radiating plications on either side. About 6 distinct radiating plications on each side of the median groove.

Brownsport bed: Bath Springs, Tennessee.

A study of the various specimens of *Homœospira* at hand suggests that there is considerable variation in the appearance of the plications which occupy the median groove even within the limits of the same species so that characters drawn from this source are considered of doubtful value. A single plication may begin at different distances anterior to the beak and may or may not bifurcate anteriorly; in case it bifurcates the two branches may be very fine and remain very close together, or they may separate more or less; they may separate so far as to occupy a position along the side walls of the groove. In some cases these median plications may so nearly equal the size of the plications on either side that only their later insertion at a greater distance from the beak distinguishes them readily. Sometimes two plications are inserted side by side along the median groove and increase in size anteriorly or remain comparatively small. Nevertheless differences in form are noticed which are sufficiently constant to suggest the presence of different species. These differences consist chiefly in differences in the lateral outline, the convexity, and the coarseness and distinctness of the plications. The amount of overarching of the beak of the pedicel valve varies considerably in the same species.

Cyrtia cliftonensis.

(*Plate II, Fig. 32.*)

Height of cardinal area, 6 mm.; width, 10 mm.; margins of sinus of ventral valve distinct and angular, diverging at an angle of about 52°; lateral outlines of the cardinal area form an angle of about 82° at the beak; the cardinal area forms an angle of about 69° with a plane resting upon the margins of the sinus. Although the sinus is sharply defined laterally, it is of only moderate depth; in a similar manner the elevation of the median fold on the dorsal valve is moderate. Surface with very fine radiating striæ, seen only under a lens. Width of delthyrium at hinge line about 1 mm.; foraminal groove of the deltidial covering apparently very long and narrow but not well preserved.

Brownsport bed: Clifton, at the top of the hill back of the town, Tennessee.

Reticularia pegramensis.

(*Plate II, Fig. 31 A, B.*)

Length, 15 mm.; width, 19 mm.; thickness, 10.5 mm. Valves subequally convex; median fold of brachial valve low but distinct owing to a slight depression of the shell along each side, width of fold 5 mm. at the anterior margin of the shell; median depression of the pedicel valve shallow. No lateral folds or plications. Surface with concentric markings as in *Reticularia fimbriata*. Sides of the fold diverging at an angle of about 20°. Probably identical with *Reticularia proxima*, described by E. M. Kindle from northern Indiana.

Brownsport bed: Pegram, Tennessee.

Spirifer geronticus.

(*Plate II, Fig. 30 A, B.*)

Width of largest specimen found, 24 mm. Fold of brachial valve, low, rendered more distinct by a narrow depression of the shell or groove, on each side; sides of fold diverge at an angle of 27°; the groove is most distinct at the beak. On each side of the fold is a plication which is distinct at the beak but becomes faint and disappears about 14 mm. from the beak; a second plication on each side becomes faint about 4 mm. from the beak. Sinus of the pedicel valve sharply defined laterally, the margins of the same being formed by a plication which is distinctly defined by a groove along its posterior part, the groove becoming less distinct anteriorly. In addition to the plication which borders the sinus there is a second plication on each side which disappears about 6 mm. anterior to the beak. It is evident that the shell possesses a larger number of plications in its earlier stages of growth than it continues to develop during its later stages, the ornamentation becoming more simple at maturity. Surface with numerous fine radiating striæ.

Brownsport bed; glade southwest of Dixon Spring; hill east of Clifton; four miles northwest of Martins Mills; south of Mr. Phillips'; Pegram, Tennessee.

Spirifer swallowensis.

(*Plate II, Fig. 33.*)

Resembles *Spirifer crispatus*, but, in addition to the median fold of the brachial valve and the two plications forming the sides of the median sinus on the pedicel valve, there is on each side only one well developed lateral plication in place of two as in the case of *Sp. crispatus*, and the concentric lamellæ appear coarser. Length, 11.5 mm.; width, about 14 mm.; thickness, 9.5 mm.

Waldron bed: Swallow Bluff, north of landing, Tennessee.

Atrypa reticularis-newsomensis, var. nov.

(*Plate I, Figs. 11 A, B.*)

The assigning of a distinct name to this very common form of *Atrypa reticularis* is due merely to the convenience which a distinct name offers when it is desired to record in the field the particular variety which is present at any locality. It is not expected that this name will find general use. Radiating plications coarse, 8 or 9 in a width of 10 mm. Shell of medium size. Types from Waldron bed at Newsom, Tennessee.

Atrypa reticularis-niagarensis was figured by Nettelroth in Fossil shells of the Silurian and Devonian rocks of Kentucky, 1889, plate 32. There are from 12 to 14 plications in a width of 10 mm. The form of the shell is more variable than the figures by Nettelroth suggest. It is the form figured by Roemer, fig. 9, plate 5, in his work on the *Silurian Fossils of Western Tennessee.*

Atrypa arctostriata.

(*Plate II, Figs. 34 A, B.*)

Probably only one of the many varieties of *Atrypa reticularis* but apparently more distinct than the greater number of these forms. About 28 radiating plications in a width of 10 mm. Fimbriate margin at different stages of growth well preserved. Shell of only moderate convexity, a specimen 15.5 mm. long and 18.5 mm. wide having a vertical dimension of only 7.5 mm.

Brownsport bed; glade southwest of Brownsport Furnace, three miles west of Vice landing, Tennessee.

Rhynchotreta simplex, sp. nov.

(*Plate III, Figs. 46, A, B.*)

Shell triangular, cuneiform, tapering posteriorly into an angular beak. Width of one specimen, 11 mm.; thickness, 5 mm.; length, estimated at 13 mm. Both valves moderately convex. In the pedicel valve the teeth are supported by thin vertical lamellæ which border a long, narrow, deep pedicel scar; muscular impressions faint, probably 3 mm. long, extending to within 8 mm. of the anterior margin of the shell. Brachial valve with a median septum Cardinal slopes long and flattened. Plications about 12; no evidence of fold or sinus. Shell apparently remaining in the neanic stage. No reversal of curvature is noted.

Compared with *Rhynchotreta transversa*, Weller, this species has a greater number of plications.

Clinton bed: from the weathered brown chert found near the cement mill, at the southern end of Clifton, along the river. Tennessee.

Rhynchotreta thebesensis, sp. nov.

(*Plate IV, Figs. 66, A, B, C.*)

Shell cuneiform, with long flat sides diverging at an angle of 60° to 70°, with an acuminate beak. The anterior outline is rounded, and the depth of the shell is considerable for one of this type. In a shell having a width of 14.5 mm., the depth was 10.5 mm., the length of the brachial valve was 14.5 mm., and the length of the pedicel valve was estimated at slightly over 15.5 mm. Near the beak of the brachial valve a few specimens show a slight median concavity. The two median plications are slightly raised anteriorly above the general convexity of this part of the shell. On each side of these median plications there are four distinct and 1 indistinct plication, reduced sometimes to 3 distinct and 1 indistinct one. On the pedicel valve there is a median plication with 4 distinct and 1 indistinct plication on each side. This median plication, in some specimens, terminates in a slight depression anteriorly, in others the plication on each side of the median plication also is involved so that there is a broad flattening or slight depression, without the appearance of a sinus. There is no evidence of a deltidium partly closing the delthyrium.

Strata of uncertain age, but evidently lower Niagaran. Thebes, Illinois.

Rhynchotreta thebesensis occurs in a layer of rather coarse grained crystalline limestone, 3 feet thick, forming the top of the exposure along the river bank a mile north of Thebes. This layer contains *Lichas breviceps-thebesensis*, a form differing from the variety *clintonensis* only in having a pygidium of a slightly more triangular outline than the common Clinton variety. In addition to this, pygidia occur which cannot be distinguished from *Phacops pulchellus*, and others which differ from *Dalmanites werthneri* only in having a terminal spine, 1 mm. in length. *Whitfieldella billingsiana*, Meek and Worthen, is closely related to *Whitfieldella cylindrica*. *Pterinea thebesensis*, Meek and Worthen, may be related to *Pterinea rhomboidea*, Hall. *Atrypa calvina*, Nettleroth, not known from strata as early as the Clinton elsewhere. *Leptæna rhomboidalis*. *Lyellia thebesensis*, forming massive coralla with the walls of neighboring corallites almost in contact with each other, leaving very small interspaces for the *cænenchyma*. The tabulæ average about 8 or 9 in a length of 5 mm., and the plates in the intermediate spaces are more numerous, but not distinctly vesicular. The diameter of the corallites is slightly more than 1 mm. The walls of the corallites are slightly crenulated, and are slightly striated lengthwise. No septa are visible. See figures 69 A B on plate IV of this Bulletin.

Beneath the coarse grained limestone carrying the preceding fauna there is a layer of clay shale one foot thick, underlaid by a layer of limestone, seven inches thick, containing *Dalmanites danæ*, Meek and Worthen, *Schuchertella subplana*, *Pterinea thebesensis*, Meek and Worthen, and a large form resembling *Meristina maria*. These species of *Dalmanites*, *Orthothetes*, and *Meristina* suggest later age than the Clinton of Ohio, so that the overlying fauna may be regarded as of later than Clinton age, but with a recurrence of some species elsewhere known in the Clinton.

Beneath the *Dalmanites danæ* layer, there are found, in descending order, shale 2 inches thick; limestone, 4 inches thick, wavy at the base; shale, 14 inches thick; a layer of limestone, 8 inches thick. The latter contains *Cyphaspis girardeauensis*, Shumard; *Proetus depressus*, Shumard; *Encrinurus deltoideus*, Shumard; *Acidaspis halli*, Shumard: *Orthis* (*?Schuchertella*) *missouriensis*, Shumard; *Leptæna* (*?Brachyprion*) *mesacosta*, Shumard; *Tentaculites incurvus*, Shumard, and a species of *Cornulites*. This layer evidently contains the fauna described by Shumard from the Cape

Girardeau limestone. This fauna has a Silurian aspect, and here forms the base of the Niagaran section apparently. The fossiliferous layer of limestone here described, and the underlying thin bedded layers, are more or less oolitic and form a section about 33 inches thick a short distance south of the exposures containing the upper faunal layers here described. There is a line of unconformity beneath, indicated by a wavy surface of the underlying rock, along an irregular contact, marked 100 feet south of the main fossil locality by a series of nodular masses occurring at successively higher elevations in the series.

Rhynchonella (Stegerhynchus) whitii-præcursor, var. nov.

(*Plate III, Figs. 47 A, B, C.*)

Lateral outline broadly ovate, both valves convex, the convexity of the brachial valve being slightly greater. The pedicel valve is distinctly flattened from the point where the plates supporting the teeth terminate on the interior of the shell as far as the point where the downward curvature of the shell at the anterior margin begins. In one specimen, a cast of the interior, with a length of 8 and a width of 9.5 mm., the depth is 7 mm. In most other specimens, possibly less mature, the depth is nearer 5 or 6 mm. Two plications occupy the median fold of the brachial valve rising scarcely a millimeter above the neighboring plications. A single plication occupies the sinus of the pedicel valve. This plication equals in size the plications bordering the sinus.

Interior of the brachial valve marked by plications where the exterior is marked by the grooves between the plications. This results in a median elevation in the interior of the brachial valve. While the other plications on the interior of the valve become indistinct before reaching the crural plates, the median plication is strengthened by a thickening of the shell posteriorly and forms a median elevation which broadens slightly on reaching the anterior margin of the crural plates, apparently filling in the space just beneath these plates. The crural plates present a slightly concave surface approximately parallel to the plane of the valve, and project forward at their inner angles so as to form crural tips. The shell beneath the crural plates is thickened and filled out so that only a narrow space is left between these plates, and this space is occupied by a very narrow, linear septum, representing the cardinal process.

The teeth of the pedicel valve are supported by vertical dental lamellæ, enclosing a cavity of ovate form, distinctly outlined in natural casts of the shell. None of the casts shows a distinct muscular area, but in an indistinct manner this area is represented by the indistinctness of the median plication of the cast, extending to a point 3.7 mm. from the beak. In the cast of this muscular area there is a slight and narrow median depression, and another is shown laterally, suggesting the muscular area of *Rhynchotreta*.

Clinton bed: Clifton, Tennessee.

Compared with *Rhynchonella bidens*, the angulation produced by the fold and sinus along the anterior margin of the valves is much less, and the pedicel valve is less convex. The sinus and fold are relatively broader, and the lateral plications usually number three rather large ones, and one much smaller, the latter sometimes indistinct. It evidently is closely related to *Rhynchonella whitii*, from which it differs chiefly in the smaller size, and the less prominent fold and sinus.

Rhynchonella (Stegerhynchus) neglecta-cliftonensis, var. nov.

(Plate III, Figs. 48, A, B, C.)

This shell is unquestionably congeneric with *Rhynchotreta whitii-præcursor*. The brachial valve possesses the same crural plates terminating anteriorly at their inner angles with crural points. These crural plates rest upon the thickened shell beneath but are separated from each other by a space within which the thin longitudinal cardinal process may be seen distinctly. The teeth of the pedicel valve are supported by dental lamellæ, and anterior to the space thus enclosed may be seen the faint traces of the muscular area. The latter is indicated chiefly by the diminished distinctness of the plications which correspond to grooves between the plications of the exterior of the shell.

There are four plications on the median fold, with 3 distinct and 1 indistinct plication on each side, on the brachial valve. In the sinus of the pedicel valve, there are three plications, with 4 distinct and 1 nearly obsolete plications on each side.

Compared with *Rhynchonella neglecta*, from the Clinton group of New York, the shell is larger, broader, less triangular, flatter along the middle parts of the pedicel valve, and the number of lateral plications is smaller.

Clinton bed: Clifton, Tennessee.

According to the preceding observations, *Rhynchonella whitii*, *Rh. neglecta*, and *Rh. indianensis* are congeneric. This group is believed to include also *Rhynchonella bidens*, and *Rhynchonella acinus*. That these shells do not belong to *Camarotoechia* is shown by the thin, lamellar cardinal process. That they do not belong to *Rhynchotrema* is shown by the much smaller, oval muscular area, quite different in form and in the general arrangement of the muscular markings. The nearest relative undoubtedly is *Rhynchotreta cuneata*, to which genus it may belong. To determine this, the delthyrium must be studied. This delthyrium is not preserved in the specimens at hand in such a form that any opinion can be expressed with confidence. The general form of *Rhynchotreta* is very different, but this may be a specific, rather than a generic characteristic. To distinguish the species typified by *Rhynchotreta whitii-præcursor*, from the more typical species of *Rhynchotreta*, possessing an acuminate beak, long broad flattened sides, and a median depression along the posterior parts of the brachial valve, the term *Stegerhynchus* may be employed.

Camarotoechia lindenensis.

(*Plate I, Fig. 13.*)

The generic affinities of this shell can not be determined definitely since the interior is unknown and the tip of the beak is poorly preserved; however, as far as can be determined the beak of the pedicel valve was not perforated. Outline approximately circular; length, 19 mm.; width, 23 mm.; thickness, about 11.5 mm. The specimen may have been thicker originally, but it evidently consisted of a shell of only moderate convexity. Median fold and sinus distinct, rather narrow and of only moderate elevation and depth, the fold rising only 2.5 mm. above the adjacent part of the shell at the anterior margin. Three radiating plications on the median fold, two in the sinus, 8 or 9 on each side. Plications rather sharply angular along the top, crossed by fine close striæ distinctly visible under a lens.

Brownsport bed: near E. Duncan, one and one-half miles east of Linden, Tennessee.

Uncinulus schucherti.

(*Plate I, Fig. 19.*)

Shell resembles *Wilsonia saffordi*, but that part of the ventral valve occupying the fold projects far less beyond the lateral margins of the shell. The dorsal valve is more evenly convex. The anterior face of the shell is not flattened, so that a profile view is less angular. Plications on the mesial fold vary from 4 to 5; of the lateral plications 7 to 10 are distinct, and 2 to 4 indistinct. Largest specimen, 15 mm. long. Globular or moderately elongated. Named in honor of Mr. Charles Schuchert.

Linden bed; above the quarry north of Perryville, Tennessee.

Stephanocrinus tennesseensis.

(*Plate I, Figs. 4 A, B.*)

Closely related to *Stephanocrinus osgoodensis*. Body approximately inversely conical, the sides diverging at angles varying from 50° to 60°; constriction at base usually slight; base usually sharply pointed and triangular in cross-section; some specimens less acute at the base; cavity for reception of stem either very minute or obsolete. Length to base of ambulacral grooves 6.5 to 7.5 mm.; length of interambulacral projections of the body, 2 mm. Surface granulose; the granules are arranged more or less serially in directions corresponding to that of the striæ of the distinctly striated species, and in these directions the granules are usually more or less elongated, but at first sight the granulation is more obvious than is the arrangement of the granules according to some design. In *Stephanocrinus osgoodensis* the surface is traversed by fine closely arranged striæ, the base is less acute, more triangular below, and the cavity for the insertion of the stem is more distinct.

Waldron bed: Iron City, at station; Clifton, three-quarters of a mile above landing, along the river; Swallow Bluff, along upper part of bluff south of landing; along road leading east from New Era, following the Waldron bed outcrop for a considerable distance; all in Tennessee.

Eucalyptocrinus springeri, sp. nov.

(*Plate IV, Fig. 73.*)

This species is closely related to *Eucalyptocrinus elrodi*, from the Waldron bed, at Waldron, Indiana, but differs in the charac-

ter of the surface ornamentation. In a calyx 44 mm. in width the margins rise only 13 mm. above the base. The basal cavity has a width of 7 mm. Surface nearly smooth, but under a lens the plates are seen to be covered by a network of fine lines radiating in an irregular manner in sets from various centers, the lines bending in an irregular vermiculiform manner. Named in honor of Mr. Frank Springer.

Waldron bed: Newsom, Tennessee.

Heliophyllum pegramensis, sp. nov.

(*Plate III, Fig. 58 A, B.*)

Corallum simple, small, short and broad, arising from a very oblique base. Diameter of calyx rarely exceeding 25 mm.; corresponding height, 15 mm., the tip of the base usually extending beyond the vertical projection of the margin of the calyx. Width of calyx in a specimen 25 mm. wide is about 15 mm.; depth of calyx about 7 mm., but the upper margins of the corallum are flattened, as is frequently the case in *Heliophyllum*. Vertical septa, 63 to 68; equal in size at the margin of the calyx, but half way down the calyx the alternate septa are adnate to the primary ones. At the base of the calyx the septa are twisted to the right on approaching the center. Only a slight indication of a septal fossette is found in the calyx, on the convexly curved side of the corallum.

Brownsport bed: Pegram, Tennessee.

Favosites obpyriformis.

(*Plate IV, Fig. 74.*)

Coralla chiefly in nearly globular masses, sometimes inversely pear-shaped, possibly formerly covered with an epitheca toward the base, but no trace of this is found in the specimens at hand. Some specimens attain a height of 12 cm. The corallites vary from 3 to 4 mm. in width, averaging probably nearer 3 mm. Connecting pores large and distant, on the flat walls as well as near the angles of the corallites. Apparently these pores tend to be more frequent near the horizontal diaphragms, so that they tend to be arranged in series at various levels. These diaphragms frequently are distinctly deflected downward at various parts of

the periphery, probably at about those points where the walls of the corallites are pierced by the pores.

Brownsport bed: glade northwest of the home of Charles McClanahan, two miles west of Vice Store, Tennessee.

Chonophyllum (Craterophyllum) vulcanius.

(*Plate I, Fig. 12.*)

Resembles *Chonophyllum canadense*, Billings, as figured by Lambe in *Revision* of the genera and species of Canadian paleozoic corals, 1901. Corallum simple, width 65 mm.; base flat, covered by concentrically wrinkled epitheca. Top fancifully compared with surface of a low volcano. The vertical dimensions at the center are 10 mm.; at 6 mm. from the center of the corallum, 15 mm.; at 17 mm. from the center, 4 mm.; toward the margin the corallum is reduced to a thin sheet. Septa represented at the base of the inner walls of the calyx or crater by about 74 vertical striations which increase in width toward the upper edge of the crater, continuing thence as low broad radiating plications increasing in width as far as the margin of the corallum. A narrow but distinct groove separates these plications along the extracalicular surface. There is no evidence of septa in the extracalicular part of the corallum, nor could any be detected in the central part. The radiating plications are evidently thin horizontally developed sheets, united along their adjacent edges so as to form a continuous expansion, radially grooved, covering the extracalicular surface. Corallum formed by the superaddition of successive expansions. Inner structure between successive expansions entirely vesiculose, composed of convex blister-like plates, irregularly arranged without reference to the radiating grooves traversing the expansions. On close inspection, the location of the blister-like plates may be detected on the upper surface of the expansions. Viewed from beneath, the grooves appear as raised lines, often crossing the concave surfaces of the blister plates. Structure of corallum not preserved at base of calyx or crater; no evidence of tabulæ or of distinct septal plates in this part of the corallum. No distinct concentric striations on the upper, calycular, surface of the corallum. While probably congeneric with *Chonophyllum canadense*, this could not be determined from the specimen at hand.

Brownsport bed: half a mile west of Dr. Evans's, west of Hope creek, Tennessee.

For those chonophylloid corals which have a flat base, upon which the calycular side arises in a manner resembling a low volcanic crater, the designation *Craterophyllum* is proposed. This term includes *Craterophyllum vulcanius* from the Brownsport bed, *Craterophyllum canadense* from the Anticosti Group, and an undescribed species from the Devonian limestone at Louisville, Kentucky.

Diphyphyllum proliferum.

(*Plate I, Figs. 18 A, B, C, D.*)

This species is closely related to *Diphyphyllum rugosum* as figured by Rominger from Louisville, Kentucky, on plate 45, vol. iii, *Geological Survey of Michigan.* Rominger mentions that the gemmation from the calyces is very prolific; from 4 to 6 gemmæ grow at once from an end cup. In the Tennessee specimens 4 gemmæ are common, 6 are very rare. Rominger states that the lateral processes for mutual attachment of the stems are acanthiform and quite numerous; in the Tennessee specimens, however, no lateral processes were noted, and therefore they can hardly be numerous even if present. Moreover, the Tennessee specimens can hardly be said to be annulated by subregularly repeating constrictions, the constrictions hardly being sufficiently pronounced to constitute annulation. In fact, Rominger's figure shows comparatively little strong annulation.

The figure by W. J. Davis, on plate 109 of *Kentucky Fossil Corals*, 1885, appears more typical as regards annulation and the presence of numerous acanthiform processes. The form figured as *Eridophyllum sentum*, on plate 108, appears to have septa extending as superficial carinæ of the tabulæ quite to the center of the calyx. In the Tennessee specimens there are between 40 and 50 septæ, crenulated, of two orders, alternating, the primaries usually extending only a slight distance beyond the margin of the tabulæ, but in one calyx extending as superficial carinæ of the tabula almost to the center. The tabulæ occupy the central area and the septa are confined chiefly to the peripheral cycle; there is no intermediate vertical wall. Septa connected at regular intervals by dissepiments. Diameter of stems between 7 and 11 mm. single specimens occasionally attaining a width of 14 mm. Calyx 3 to 4 mm. deep. Exterior marked by low, often indistinct, longitudinal

ridges corresponding to the spaces between the septa, crossed by fine transverse striæ and constrictions of moderate depth.

Brownsport bed: near home of E. Duncan, one and one-half miles east of Linden; also at the glade southeast of Brownsport Furnace, three miles west of Vice landing, and 8 miles east of Savannah on the Waynesboro road; all in Tennessee.

Alveolites inornatus, sp. nov.

(*Plate III, Fig. 56.*)

Corallum massive, increasing in thickness by the addition of successive layers which are adnate to one another, the later layers often projecting slightly beyond those of earlier origin so as to form an irregularly convex lower side, covered by a very thin epitheca concentrically wrinkled. The upper surface usually comparatively flat. Maximum thickness of one specimen, 32 mm.; width, 80 mm. Four to five apertures in a width of 5 mm;. upper wall of the aperture distinctly convex, its sides resting upon the median parts of the upper walls of the subjacent apertures; lower wall formed by the adjacent parts of the upper walls of the subjacent apertures. No trace of a cycle of denticules at the aperture, nor of longitudinal rows of spinules along the inner surface of the walls forming the aperture; no large marginal pores have been detected. Usually the inner walls of the aperture appear smooth but occasionally there is a longitudinal striation along the median part of the lower wall, and rarely a similar striation along the median part of the upper wall. Anterior outline of upper wall nearly straight or more or less concave. Degree of vertical compression of the aperture variable, the apertures being sometimes comparatively high as in the more typical forms of Alveolites, at other times compressed and transversely slit-like. This form was at first identified with *Alveolites niagarensis,* but the characteristic features of that species cannot be detected.

Brownsport bed: near the home of E. Duncan, one and one-half miles east of Linden, at the mouth of Jacks Branch of Short creek, Tennessee.

Pachypora (Platyaxum) pegramensis, sp. nov.

(*Plate III, Fig. 57.*)

Corallum forming flat, thin fronds, 1 to 3 mm. thick, irregularly lobate, with corallites on both sides. Corallites appearing as nar-

row tubes in the interior of the fronds, approaching the surface at a very oblique angle, rapidly widening at the surface; the upper wall thin, moderately convex, with a convex anterior outline; the lower wall formed by the general surface of the frond, concave for a short distance anterior to the margin of the upper wall; the cavity thus formed at the aperture is filled usually with clay, producing a semilunate border to the anterior edge of the upper wall, very similar to that of *Alveolites platys*. Apertures about 4 in a width of 5 mm.

Associated with these specimens are thin expansions similar to those of *Alveolites platys*, but with corallites equal in size and form of aperture to those of *Platyaxum pegramensis*. The lower surface of these expansions is covered by a wrinkled epitheca. The largest specimen has a width of 11 cm. The free edges of the expansions have a thickness of 1 to 2 mm. The anterior outline of the upper wall of many of the corallites of one specimen is concave or even V-shaped owing to the weathering back of the raised median part of the wall; at some apertures this median part of the upper wall is raised as distinctly as in *Platyaxum platys*. In another specimen the anterior part of the upper wall is only slightly convex, but the anterior outline is distinctly convex. The form of the anterior outline of the upper wall appears to be determined in part by the general curvature of the wall; where the upper wall is very depressed even along the median part the outline is more strongly convex, where the median part is distinctly raised the outline is nearly straight or moderately concave; when the median part is sharply raised the median part of the outline is often distinctly indented, and the adjacent parts project slightly. These flat expansions with a basal epitheca, which we shall call *Alveolites pegramensis* temporarily, are believed to be identical specifically with *Platyaxum pegramensis*. Although no specimens showing the mode of origin of the frondose forms are at hand, it is believed that they originate locally from parts of the flat expansions.

Brownsport bed: bridge two miles west of Pegram, Tennessee.

Pachypora (Platyaxum) platys, sp. nov.

(*Plate I, Figs. 16, A, B, C.*)

Corallum forming flat, thin fronds, 1 to 3 mm. thick, irregularly lobate, with corallites on both sides. The interior of the frond is

dense, the corallites appearing as minute tubes traversing the dense substance at angles very oblique to the surface, gradually approaching the latter. Near the surface the tubes widen rapidly laterally, attaining a width of about half a millimeter at the apertures; they are very oblique to the surface. The apertures are strongly compressed vertically, resulting in an obliquely directed slit; the lower edge of the aperture gradually rises above the surface of the frond, the calyx widening from the tubular portion toward the aperture; near the aperture a cross-section of the lower edge is distinctly convex along the middle and slightly concave toward the sides resulting in a more prominent elevation of the median part of the wall. The outline of the lower margin of the aperture is concave along the median part, often becoming convex at the sides where the sides of the lower edge of the aperture rest upon the general surface of the frond. In well preserved specimens the concavity of the outline of the lower margin of the aperture often is slight, but in worn specimens the median parts have suffered most, and the outline of this part of the aperture is then more strongly concave, or even deeply V-shaped. The upper wall of the aperture is formed by the general surface of the frond. No septal spines or pores or longitudinal ridges were noticed along the upper wall where the upper lower edge of the aperture had been weathered away. The internal structure between the tubular passages of the corallites is unknown; the cell walls apparently are thick walled here but the structure is not clearly defined in the specimens at hand. About 7 apertures in a width of 5 mm.

Brownsport bed: near the home of E. Duncan, on Short creek, one and one-half miles east of Linden, Tennessee.

Among the species referred to *Pachypora*, there is a group characterized by the sharp edge of the thin, strongly flattened, more or less appressed, lower lip, which may be indented with one or two emarginations, or may weather to a deeply indented V-shaped form. Septal spines are wanting. There is no indication of an internal process or septal ridge. This group includes, in addition to *Pachypora platys*, also *Pachypora frondosa*, Nicholson, and probably also *Pachypora fisheri*, Billings. For this group the term *Platyaxum* is here used.

Pachypora (Platyaxum) planostiolata, sp. nov.

(*Plate III, Fig. 55.*)

At the bridge west of Pegram, specimens occur which differ from *Platyaxum platys* chiefly in their mode of growth. They form thin expansions, increasing in thickness by a succession of superimposed layers which often are more or less free toward the margin. The lower side of the corallum and of all of the free parts of the successive expansions is covered by a concentrically wrinkled epitheca. The largest specimen at hand, when complete, must have had a diameter of about 25 cm., and a thickness at the center of at least 15 mm. The free parts of the expansions frequently are less than 2 mm. thick.

The corallites are very oblique to the surface and have very depressed apertures. There is a great variation in the form of the aperture, depending in part on the state of preservation. In most well preserved specimens the lower edge or lip of the aperture is slightly convex and the anterior outline of this wall is distinctly, sometimes strongly convex, producing a lunate aperture. The upper margin of the aperture, formed by the general surface of the corallum, is often distinctly concave for a short distance anterior to the lower edge or lip. A semi-lunate mass or line of clay often appears in the aperture, indicating its form. In some specimens the lower edge or lip of the aperture is distinctly elevated along the median line, the elevation being bordered by narrow, though shallow, depressions on either side. In these cases that part of the anterior margin of the lower lip which is anterior to the grooves often projects slightly farther forward, while the median part is slightly indented, giving a slightly dentate appearance to the anterior outline of this lip. The median parts of the lower lip, when distinctly elevated, often are worn back, as in *Platyaxum platys*. In some worn specimens a distinct longitudinal ridge appears to be present on the interior of the corallite, along the upper wall; in others, it cannot be detected; possibly cross-sections might show it. About 7, sometimes 5, apertures occupy the width of 5 mm.

This species does not appear to be a true *Alveolites*, although specimens congeneric with it appear to be referred usually to that genus. In *Cœnites* the corallites bend abruptly toward the surface meeting the latter almost at right angles, the walls being thickened abruptly near the surface. These features are not noticed in the

specimens here described. It is believed that further study will prove this species to be congeneric with *Platyaxum platys* although at present the different forms of growth must distinguish them.

Brownsport bed: railroad bridge two miles west of Pegram, Tennessee.

Caryomanon patei, sp. nov.

(*Plate I, Fig. 15.*)

Sponge distinctly flattened on what is assumed to be the lower side. Upper side strongly convex, rounding into the base. Upper surface marked by rather shallow channels which tend to occur in pairs or in groups of three, but this grouping is not very evident. Some of the deeper channels give a slight lobation to the lower parts of the side of the sponge, but this lobation also is very indistinct. The oscula, almost a millimeter in diameter open in these radiating channels, especially along the upper part of their length. The channels become indistinct about 7 to 9 mm. from the center of the top of the sponge. The largest specimen found is 43 mm. in width, and 21 mm. in height.

Brownsport bed: near the A. B. Gant place, northeast of Martins Mills, in Tennessee. Species named in honor of Mr. W. F. Pate, whose collections have contributed greatly of our knowledge of the Silurian formations of western Tennessee.

PLATE I.

FIG. 1. Pentamerella manniensis. *A*, *D*, pedicel valves. *B*, *C*, brachial valves. Northwest of Riverside, Tennessee. Clinton bed.

FIG. 2. Stricklandinia dichotoma. *A*, Riverside. *B*, Iron City, Tennessee. Clinton bed.

FIG. 3. Hyolithus newsomensis. *A*, dorsal side. *B*, ventral side. Newsom, Tennessee. Waldron bed.

FIG. 4. Stephanocrinus tennesseensis. *A*, *B*, Iron City, Tennessee. Waldron bed.

FIG. 5. Plectambonites tennesseensis. *A*, *B*, *C*, pedicel valves. *D*, *E*, brachial valves. Iron City, Tennessee.

FIG. 6. Anoplothecas affordi. Pedicel valve. Gant Place. Northeast of Martins Mills, Tennessee. Brownsport bed.

FIG. 7. Homœospira pisum. Brachial valve. Bath Springs, Tennessee. Brownsport bed.

FIG. 8. Homœospira beecheri. *A*, pedicel valve. *B*, brachial valve. Brownsport furnace, Tennessee. Brownsport bed.

FIG. 9. Homœospira schucherti-elongata. *A*, pedicel valve. *B*, brachial valve. Bath Springs, Tennessee. Brownsport bed.

FIG. 10. Homœospira schucherti. *A*, pedicel valve, *B*, brachial valve. Brownsport Furnace, Tennessee. Brownsport bed.

FIG. 11. Atrypa reticularis-newsomensis. *A*, *B*, pedicel valves. Newsom, Tennessee. Waldron bed.

FIG. 12. Chonophyllum (Craterophyllum) vulcanius. West of Dr. Evans, west of Hope creek, Lewis county, Tennessee. Brownsport bed.

FIG. 13. Camarotoechia lindenensis. East of Linden, Tennessee. Brownsport bed.

FIG. 14. Diaphorostoma brownsportensis. Brownsport furnace, Tennessee. Brownsport bed.

FIG. 15. Caryomanon patei, nov. sp. Gant Place, two miles northeast of Martins Mills, Tennessee. Brownsport bed.

FIG. 16. Pachypora (Platyaxum) platys. *A*, three fragments placed arbitrarily so as to suggest lobation of the frond. *B*, *C*, basal fragments referred to this species. East of Linden, Tennessee. Brownsport bed.

FIG. 17. Rhipidomella saffordi. *A*, *B*, brachial valves. *C*, pedicel valve. Gant stables, northeast of Martins Mills, Tennessee. Brownsport bed.

FIG. 18. Diphyphyllum proliferum. *A*, *B*, side views of budding stems. *C* top view of budding stem. *D*, calycular view. East of Linden, Tennessee., Brownsport bed.

FIG. 19. Uncinulus schucherti. View from side of brachial valve. Perryville, Tennessee. Linden bed.

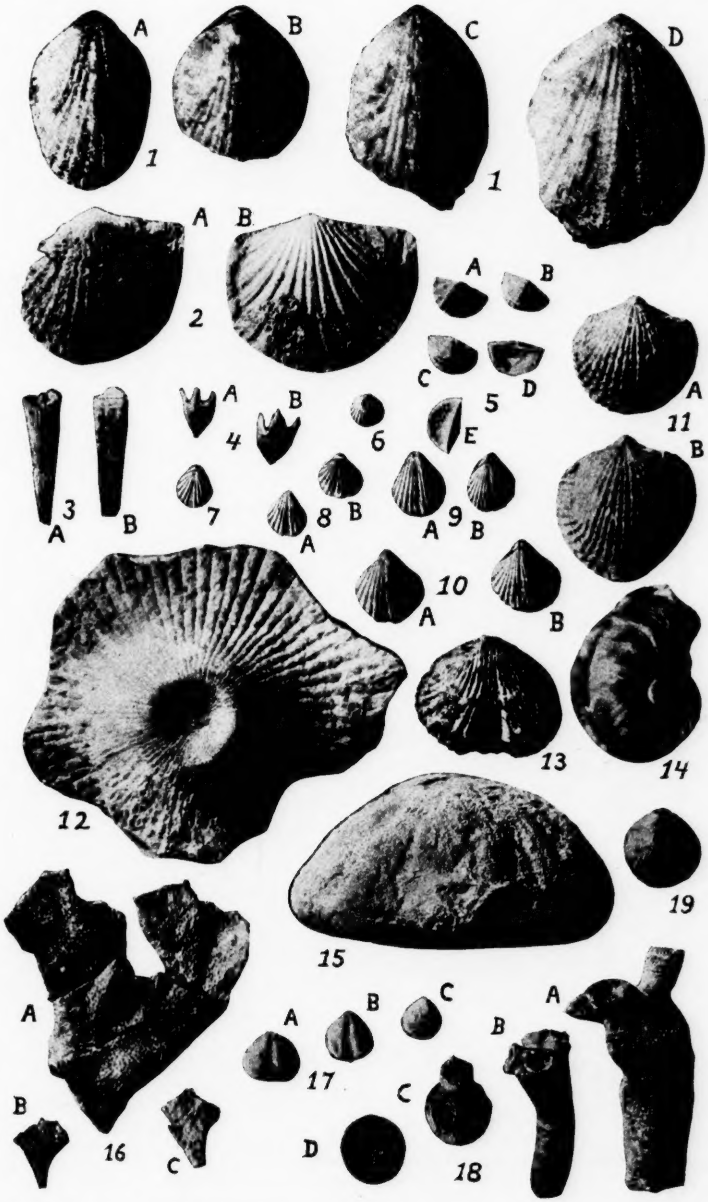
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PLATE II.

FIG. 20. Strophonella tenuistriata. *A*, pedicel valve, from Cerro Gordo. *B*, brachial valve, from New Era. Both from Tennessee. Brownsport bed.

FIG. 21. Strophonella dixoni. Brachial valve. Dixon Spring, Tennessee. Brownsport bed.

FIG. 22. Strophonella ganti. Brachial valve. Gant place, northeast of Martins Mills, Tennessee. At base of Gant division of Brownsport bed.

FIG. 23. Strophonella prolongata. *A*, *B*, brachial valves. Brownsport Furnace, Tennessee. Brownsport bed.

FIG. 24. Strophonella rœmeri. Brachial valve. Brownsport Furnace. Brownsport bed.

FIG. 25. Strophonella laxiplicata. *A*, pedicel valve. *B*, Fragment of pedicel valve, with striæ more prominent than usual at the beak. Brownsport Furnace. Brownsport bed.

FIG. 26. Strophonella semifasciata-Brownsportensis. Fragment of brachial valve. Brownsport, Tennessee. Brownsport bed.

FIG. 27. Schuchertella rœmeri. *A*, *C*, brachial valves. *B*, ventral valve. Dixon Spring, Tennessee. Brownsport bed.

FIG. 28. Rhipidomella lenticularis. *A*, brachial valve. *B*, pedicel valve. Brownsport Furnace, Tennessee. Brownsport bed.

FIG. 29. Meristina maria-rœmeri. *A*, brachial valve. *B*, Anterior view. Glenkirk, Tennessee. Brownsport bed.

FIG. 30. Spirifer geronticus. *A*, cardinal view. *B*, Ventral valve, fragment. Dixon Spring, Tennessee. Brownsport bed.

FIG. 31. Reticularia pegramensis. *A*, pedicel valve. *B*, brachial valve. Pegram, Tennessee. Brownsport bed.

FIG. 32. Cyrtia cliftonensis. Pedicel valve. Clifton, Tennessee. Brownsport bed.

FIG. 33. Spirifer swallowensis. Brachial valve, photographed in an inverted position in order to indicate the concentric striæ better. Only two plications are shown here, one of which corresponds to the median fold; the other is the lateral plication. Swallow bluff, Tennessee. Waldron bed.

FIG. 34. Atrypa arctostriata. *A*, pedicel valve. *B*, brachial valve. Brownsport Furnace. Brownsport bed.

FIG. 35. Conchidium lindenensis. Pedicel valves. Coon creek, east of Linden, Tennessee. Brownsport bed.

FIG. 36. Conchidium legœnsis. Northeast of Lego, Tennessee. Brownsport bed.

A. F. Foerste

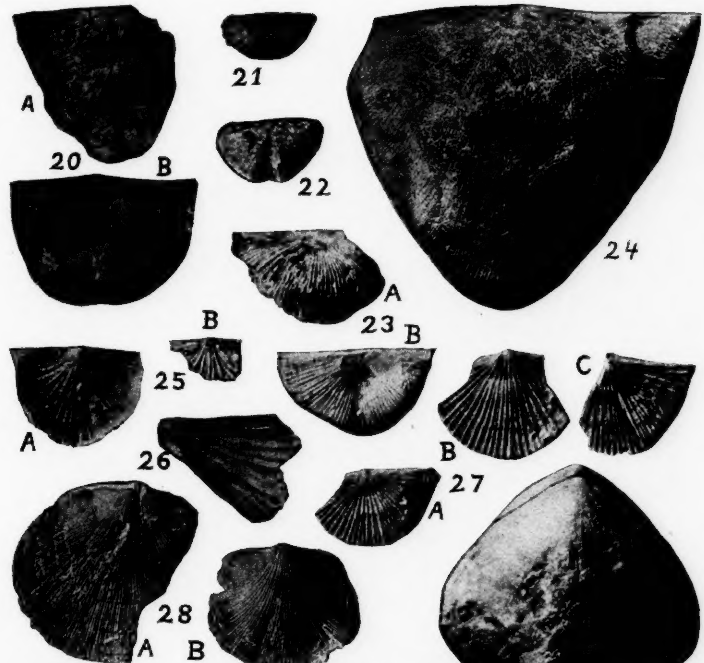

PLATE III.

FIG. 37. Cyrtoceras cinctutus. *A*, lateral view. *B*, dorsal view. Clifton, Tennessee. Osgood bed.

FIG. 38. Hyolithus cliftonensis. *A*, Ventral view. *B*, Dorsal view. Clifton, Tennessee, Osgood bed.

FIG. 39. Triplecia (Cliftonia) tenax. Clifton, Tennessee. Osgood bed.

FIG. 40. Platyceras pronum. View of upper side. Clifton, Tennessee. Osgood bed.

FIG. 41. Diaphorostoma cliftonensis. *A*, side view. *B*, view showing aperture. Clifton, Tennessee. Osgood bed.

FIG. 42. Triplecia (Cliftonia) striata. *A*, brachial valve. *B*, pedicel valve. Clifton, Tennessee. Clinton bed.

FIG. 43. Orthis flabellites. Brachial valve. New Marion, Indiana. Osgood bed.

FIG. 44. Orthis interplicata. Brachial valve. New Marion, Indiana. Osgood bed.

FIG. 45. Hebertella (Schizonema) fissistriata. *A*, brachial valve. *B*, interior of brachial valve. New Marion, Indiana, Osgood bed.

FIG. 46. Rhynchotreta simplex. *A*, pedicel valve. *B*, brachial valve. Clifton, Tennessee. Clinton bed.

FIG. 47. Rhynchonella (Stegerhynchus) whitii-præcursor. *A*, *B*, brachial valves. *C*, pedicel valve. Clifton, Tennessee. Clinton bed.

FIG. 48. Rhynchonella (Stegerhynchus) neglecta-cliftonensis. *A*, brachial valve. *B*, pedicel valve. *C*, anterior view. Clifton, Tennessee. Clinton bed.

FIG. 49. Wilsonia saffordi. Lateral view, with the pedicel valve on the right. Brownsport Furnace, Tennessee. Brownsport bed.

FIG. 50. Uncinulus schucherti. Lateral view. Ferryville, Tennessee. Linden bed.

FIG. 51 A, B. Gypidula simplex. *A*, pedicel valve. *B*, view from side of brachial valve. Newsom, Tennessee. Waldron bed.

FIG. 51 C. Gypidula rœmeri. Pedicel valve. Newsom, Tennessee. Waldron bed.

FIG. 52. Chonostrophia lindenensis. Pedicel valve. Pyburn bluff, Tennessee. Linden bed.

FIG. 53. Hebertella celsa. *A*, Interior of brachial valve. *B*, view from side of pedicel valve. Perryville, Tennessee. Linden bed.

FIG. 54. Hebertella (Schizonema) fissiplica. *A*, *B*, brachial valves. *C*, *D*, interiors of brachial valves. *E*, interior of pedicel valve. Dixon Spring, Tennessee. Brownsport bed.

FIG. 55. Pachypora (Platyaxum ?) planostiolata. Upper surface, showing the apertures of the corallites. Pegram, Tennessee. Brownsport bed.

FIG. 56. Alveolites inornatus. Upper surface. A mile and a half east of Linden. Tennessee. Brownsport, bed.

FIG. 57. Pachypora (Platyaxum) pegramensis. Part of a frond, with the broken edge along the lower side of the figure. Pegram, Tennessee. Brownsport bed.

FIG. 58. Heliophyllum pegramensis. *A*, Calyx. *B*, side view. Pegram, Tennessee. Brownsport bed.

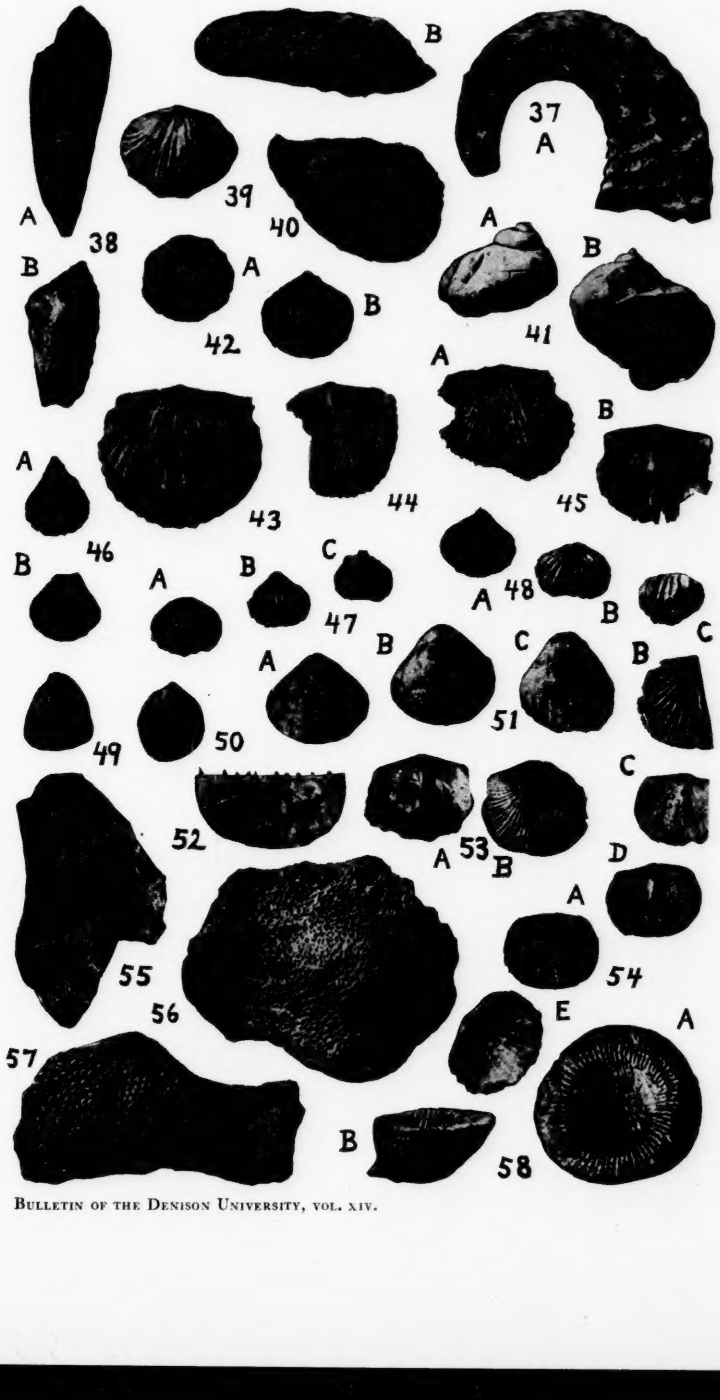
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PLATE IV.

FIG. 59. Pterinea newsomensis. *A*, Left valve. *B*, right valve, with concentric striations on the posterior wing. Newsom, Tennessee. Waldron bed.

FIG. 60. Pterinea nervata. Left valve with outline restored after comparison with Pterinea newsomensis. Between the conspicuous radiating striæ there are 2 to 3 much finer striations, not readily seen except under a lens. Newsom, Tennessee. Waldron bed.

FIG. 61. Pterinea brisa. Left valve. Newsom, Tennessee. Waldron bed.

FIG. 62. Rhombopteria (Newsomella) ulrichi. *A*, right valve, with cross-striations. *B*, left valve, with only concentric striæ, more or less lamellose. Newsom, Tennessee. Waldron bed.

FIG. 63. Rhombopteria (Newsomella) revoluta-divaricata. *A*, right valve, with posterior wing restored. *B*, left side. *C*, right valve, apparently representing a shell shorter in length but greater in height than those figured by *A* and *B*. Newsom, Tennessee. Waldron bed.

FIG. 64. Orthostrophia newsomensis. Pedicel valve, with small deep muscular area and strong vascular markings. Newsom, Tennessee. Waldron bed. Glade southwest of Dixon Spring, Tennessee. Brownsport bed.

FIG. 65. Orthostrophia dixoni. Pedicel valve, with small deep muscular area. Glade southwest of Dixon Spring, Tennessee. Brownsport bed.

FIG. 66. Rhynchotreta thebesensis. *A*, Brachial valve. *B*, Lateral outline of a thin shell. *C*, Lateral view of a more obese specimen, illuminated from the lower right hand side so as to show the flattened sides toward the beak. Beak of pedicel valve restored. About a mile north of Thebes, Illinois. In the lower part of the Silurian, about 3 feet above the Cape Girardeau limestone.

FIG. 67. Stropheodonta (Brachyprion) newsomensis. Pedicel valve. Newsom, Tennessee. Waldron bed.

FIG. 68. Scendium bassleri. *A*, Brachial valve. *B*, lateral outline. Newsom, Tennessee. Waldson bed.

FIG. 69. Lyellia thebesensis. Two specimens. About a mile north of Thebes, Illinois, 3 feet above the Cape Girardeau limestone. Silurian.

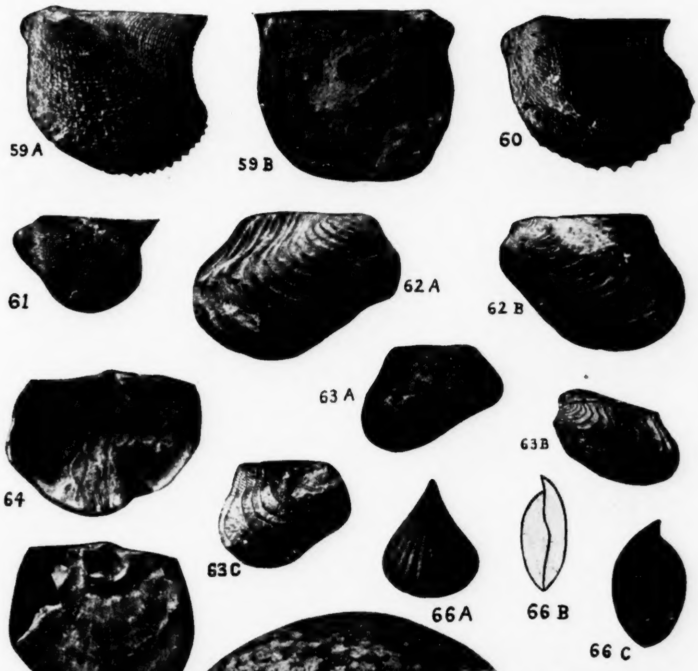
FIG. 70. Triplecia (Cliftonia) tenax. *A*, Brachial valve. *B*, Pedicel valve. Clifton, Tennessee. Osgood bed.

FIG. 71. Hebertella (Schizonema) fasciata. *A*, Pedicel valve. New Marion, Indiana. Osgood bed.

FIG. 72. Rhipidomella newsomensis. *A*, Brachial valve. *B*, Lateral view. Newsom, Tennessee. Waldron bed.

FIG. 73. Eucalyptocrinus springeri. Ornamentation too minute to be seen readily without a lens. Newsom, Tennessee. Waldron bed.

FIG. 74. Favosites obpyriformis. Part of a globular corallum 6 cm. in width. Glade 2 miles west of Vice store, Tennessee. Brownsport bed.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I. THE DETERMINATION OF TIN IN BABBITT AND OTHER ALLOYS.[1]

J. A. BAKER.

Mr. W. H. Low published a method for the "Determination of Antimony and Tin in Babbitt, Type Metal or other Alloys," which appeared in the *Journal of the American Chemical Society*, vol. xxix, no. 1, 1907. When it became necessary to make an analysis of a bronze containing copper, lead, tin, and zinc, Mr. Low's method gave promise of a rapid means of estimating the tin. It was, therefore, thoroughly tested.

Mr. Low's method for tin is as follows: Decompose the alloy with nitric acid and expel the latter by boiling with sulphuric acid till fumes of the anhydride come off thickly, add tartaric acid and potassium sulphate, heat the melt till the carbon is oxidized, cool and dilute with water. Transfer to a 500 cc. flask, add about one gram of powdered antimony, and hydrochloric acid to the extent of one-fifth the volume of the solution. Connect the flask with an apparatus capable of furnishing carbon dioxide, and while the gas is passing, heat the liquid to the boiling point, and boil for about three minutes, then cool while the current of gas is still passing.

This process leaves the tin in a proper state of oxidation to titrate with a standard iodine solution. Furthermore, according to Mr. Low, no amount of lead will interfere and "theoretically *no amount of copper* should interfere, while small amounts are known to give no trouble." Attention was attracted to the article by this last statement, for evidently the process separates neither the copper nor the lead, the former being present in solution and the latter for the most part as solid lead sulphate.

In practice in this laboratory, after bringing the solution up to the proper condition for titration according to the above directions, a few cubic centimeters of good starch solution were added, and

[1] These studies were undertaken at the suggestion of Prof. A. M. Brumback as a partial requirement for the Master's Degree.

then a few drops of standard iodine solution were run in. At the first drop a heavy, dirty-white precipitate formed. It was evident from the nature of the precipitate and the substances in solution that cuprous iodide, stained with free iodine, was being precipitated. However, several titrations were made, in the hope that the interfering action of the copper would be perfectly regular, and that a correction could be made after the amount of copper present had been determined. The addition of iodine was therefore continued till the characteristic blue coloration indicated that the end point had been attained. Care was taken to stir the solution thoroughly after each addition. The heavy precipitate present obscured the end point to some extent, but it was sufficiently well noted each time.

Three different portions of the alloy were taken, and the following results were calculated to a weight of 4 grams of the alloy. One portion required 175 cc. of the standard iodine solution, another required 133 cc., and the other required 159 cc. It was manifest that the reaction was altogether too irregular to justify any confidence in it.

The following method was finally used in the determination of the metals present in the alloy. Take portions of two or three grams each and cover with nitric acid (1:1). Action takes place at once without heating, and soon the alloy is entirely decomposed. Expel nitric fumes and add about 10 cc. of concentrated sulphuric acid. Heat till white fumes come off quickly. Cool, add 50 cc. of water, filter and wash. The lead in the precipitate may be estimated gravimetrically or volumetrically. The filtrate contains the copper, tin and zinc.

To the filtrate add enough water to make its volume up to 150 cc. Add 25 cc. of sulphuric acid. Place clean aluminum foil in the liquid and bring up to a boil. Boiling is continued till all the copper is precipitated in the metallic form. Separate the metallic copper by decantation or filtration, wash and weigh as metallic copper, after drying; or dissolve and estimate volumetrically. The copper is now entirely separated from the tin, the latter remaining in the filtrate along with the zinc which does not interfere with the estimation of the tin by iodine. The tin is now reduced by metallic antimony in a current of carbon dioxide as directed by Mr. Low, and titrated with the iodine solution.

The iodine solution produces, now, no precipitate, but the oxida-

tion goes on in a perfectly clear solution and the end point is sharply defined and unmistakable. An analysis gave the following results:

Copper	62.33
Lead	1.66
Tin	.53
Zinc	35.29
	99.81

The amounts of iodine solution required for the estimation of the tin in two samples calculated to 4 grams per sample, were as follows:

Modified method, 6.82 cc. 6.88 cc., as compared with Mr. Low's method, 133.cc., 175.cc. and 159.cc.

II. BABBITT ANALYSIS BY THE METHOD OF W. H. LOW.

The method followed in this work was that of Mr. W. H. Low, published in the *Journal of the American Chemical Society* for January 1907, with some slight modifications that seemed to be demanded by the nature of the work. It was in connection with this work that the application of the method to alloys containing large amounts of copper, was tried. The criticism of the method for such alloys appears elsewhere in these pages.

Below appears a detailed statement of what was done in applying the method. Standard solutions of ammonium molybdate, potassium permanganate, iodine and sodium thiosulphate were prepared. These were made and standardized as appears below.

I. *Ammonium molybdate.* About 9 grams of the dry salt were dissolved in each liter of water. This solution was then standardized by titrating it against thoroughly dried, pure lead sulphate. The latter was dissolved in ammonium acetate, diluted to 250 cc., acidified with acetic acid, heated to boiling and titrated, using tannin as an indicator. The tannin solution was made by dissolving tannin in about 300 parts of water. The value of the molybdate solution was calculated as follows:

Weight of $PbSO_4$ taken	= .xxxx (a)
Weight of lead in (a) = (a) × .68292	= .xxxx (b)
Volume of molybdate solution used	= .xxxx (c)
1 cc. of molybdate = (b) ÷ (c)	= .xxxxx g. Pb.

II. *Potassium permanganate.* The pure salt was dissolved in water, about 4 grams being taken for each liter of water. This was standardized according to the two following methods:

a. With metallic iron. Thin annealed wire, containing 99.6 per cent of pure iron was dissolved in dilute sulphuric acid, in an Erlenmeyer flask fitted with a Bunsen valve. Heat was usually applied to hasten solution. When solution was complete the flask and contents were cooled without removing the stopper, by holding under a stream of water. The stopper was then removed, the liquid was diluted, if necessary, with recently boiled, distilled water, and the iron was titrated with the permanganate solution to a faint pink color. The calculation for the iron value of the permanganate was made as follows:

Weight of iron wire taken	= .xxxx (*a*)
Weight of iron in (*a*) = (*a*) × .996	= .xxxx (*b*)
Volume of permanganate used	= .xxxx (*c*)
1 cc. of permanganate = (*b*) ÷ (*c*)	= .xxxxx g. Fe

b. With ferrous ammonium sulphate. Weighed portions of the salt were dissolved in acidulated water in a flask into which had been previously put a little sodium carbonate. The water was acidulated with sulphuric acid. As soon as solution was complete the iron was titrated with the permanganate solution, and the value of the latter calculated as follows:

Weight of $(NH_4)_2\,Fe\,(SO_4)_2\,.6H_2O$	= .xxxx (*a*)
Weight of iron present = (*a*) × .14251	= .xxxx (*b*)
Volume of permanganate used	= .xxxx (*c*)
1 cc. of permanganate = (*b*) ÷ (*c*)	= .xxxxx g. Fe

Since the purpose of the permanganate solution in the work undertaken was to determine antimony, the iron value as found above was calculated to the antimony value as follows:

The equations for the action of permanganate upon iron compounds and upon antimony compounds are these:

$$2KMnO_4 + 10FeSO_4 + 8H_2SO_4 = 5Fe_2(SO_4)_3 + K_2SO_4 + 2MnSO_4 + 8H_2O$$
$$2KMnO_4 + 5SbCl_3 + 16HCl = 2MnCl_2 + 5SbCl_5 + 2KCl + 8H_2O$$

It is apparent, then, that 10 atoms of iron are equivalent to 5 atoms of antimony in reducing $KMnO_4$. Hence the following proportion will give the antimony value of the permanganate solution,

letting d represent the iron value of the solution and x, the antimony value:

$$55.9 \times 10 : 120.1 \times 5 :: d : x.$$

Whence

$$x = d \times 1.075.$$

III. *Sodium thiosulphate.* Make the solution with about 19 grams of the crystallized salt per liter. Such a solution was standardized against copper sulphate, the copper content of which had been very accurately ascertained in connection with other laboratory work. The weighed amounts of the copper sulphate were dissolved in about 200 cc. of water. To this was added 5 cc. of ammonium acetate solution and 5 cc. of dilute acetic acid. Then were added about ten times the copper weight of potassium iodide crystals and the mixture stirred. The liberated iodine was titrated with the thiosulphate solution nearly to the end, when a few cubic centimeters of clear starch solution were added and the titration finished. This standard solution was used only for the purpose of standardizing the iodine solution and titrating back against the iodine solution during the estimations. The iodine value of the thiosulphate solution was calculated as follows from the reaction equation:

$$2CuSO_4 + 4KI = 2I + Cu_2I_2 + 2K_2SO_4$$

Weight of copper sulphate taken = .xxxx (a)
Percentage of copper present in the sulphate = .xxxx (b)
Weight of pure copper present = (a) × (b) = .xxxx (c)
Weight iodine equivalent to copper = (c) × $\left(\frac{126.97}{63.6}\right)$ = .xxxx (d)
Volume $Na_2S_2O_3$ used = .xxxx (e)
1 cc. thiosulphate = (d) ÷ (e) = .xxxxx g. I.

IV. *Iodine.* About 18 grams of pure potassium iodide were dissolved in 250 cc. of water and 13 grams of iodine were dissolved in the resulting solution. When solution was complete the whole was diluted to a liter. This iodine solution was titrated against measured volumes of the standard thiosulphate solution using a clear solution of starch as an indicator in just the way described above. The standard values were calculated as below:

1 cc. of thiosulphate in grams of iodine (as above) = .xxxx (a)
1 cc. of thiosulphate in cubic centimeters of I sol. = .xxxx (b)
1 cc. of the iodine solution in grams of iodine($a \div b$) = .xxxx (c)

Since this iodine solution was used in the estimation of tin, its tin value was calculated as follows from the reaction equation:

$$SnCl_2 + 2I + 2HCl = SnCl_4 + 2HI.$$

Therefore

$$Sn : 2I :: x : c$$

or

$$119 : 253.94 :: x : c$$

where c is the weight of iodine in 1 cc. of the iodine solution, and x is the weight of the tin equivalent to one cubic centimeter of the iodine solution. Then $x = (c) \times .4686$.

METHODS OF ANALYSIS.

I. *For the estimation of lead.* Samples of about 0.5 gram each were used. The alloy was in the form of fine drillings, often flattened by hammering. The samples were digested in dilute nitric acid (sp. g. = 1.20) on the water-bath for about 2 hours. The decomposition seemed to be so effected by this method of treatment that better results were obtained than by hurried decomposition at higher temperatures. When the decomposition seemed to be complete, the samples were removed from the water bath and quickly evaporated till about 5 cc. of liquid remained, then they were diluted with 100 cc. of water, boiled up, filtered and washed repeatedly with hot water. The filtrate was diluted to about 250 cc. with water (if the volume together with the washings was less than that), heated to 50° to 60° and the lead was precipitated by adding 10 cc. of sulphuric acid (1: 1). The precipitate was allowed to settle and was then filtered and washed, first with very dilute sulphuric acid and then two or three times with pure cold water. The precipitate, without separating from the filter paper, was placed in a flask and dissolved with 10 to 15 cc. of strong ammonium acetate solution. The volume was then made up to 250 cc., heated to incipient boiling and titrated with the standard molybdate solution, using tannin as an indicator. The results are recorded at the end of this paper.

II. *For the estimation of antimony and tin.* The method here described is based upon that published by Mr. Low, in the article heretofore referred to. The finely divided alloy was weighed out in samples of about 1 gram each. They were placed in an Erlen-

meyer flask and were treated with 15 or 20 cc. of concentrated sulphuric acid and 2 to 4 grams of potassium sulphate. Heat was applied till the melt was perfectly white, but care was taken not to drive off all the sulphuric acid. The samples were then cooled and diluted with 50 cc. of water and 10 to 15 cc. of strong hydrochloric acid added. Heat was applied till all possible had passed into solution. The flask was cooled and the contents rinsed into a 600 cc. beaker and diluted to 400 or 500 cubic centimeters and then titrated with the permanganate solution. The results of the estimation will be found at the end of this paper.

The method just described involves a radical departure from Mr. Low's method. Mr. Low advocates the use of hydrochloric acid solution for the titration of the antimony in which the content of HCl is about 10 per cent the volume of the solution. Attempts to use such a concentration ended in utter failure at laboratory temperatures, 20° to 22°. Very shortly after the permanganate was added the solution turned yellow, evolved the odor of chlorine and threw down a brown precipitate, all of which showed that the permanganate was being decomposed by the hydrochloric acid present. The decomposition was so energetic that absolutely no end point could be observed. The concentration recommended by Mr. Low is somewhat greater than that recommended by Fresenius and Sutton, but these authors also recommend the addition of Magnesium sulphate or other similar agent. In these experiments the volume of the acid was reduced to the proportions stated above.

The solution in which the antimony had been estimated was poured into a round bottomed flask, was rinsed out with 50 cc. of strong HCl, the rinsings being added to the contents of the flask. The solution at this point was made to contain one-fifth its volume of strong hydrochloric acid. There was then added about one gram of finely powdered antimony. The flask was shaken well and the contents digested on a water-bath till the volume was about 300 cc. The flask was next connected with an apparatus for delivering a rapid stream of CO_2, connection being made so that bubbles of the gas passed rapidly through the solution. While the gas was passing, the flask was heated to boiling and maintained at the temperature for about fifteen minutes. This was long enough to secure the reduction of all the tin. While

the gas was still passing the flask and contents were cooled by pouring cold water over the former. The flask was then disconnected from the apparatus, 5 cc. of good starch solution were added to its contents and titration was effected by means of the standard iodine solution. The thiosulphate solution was used to tritrate back if the end point was passed. The results for tin are here tabulated:

Analytical Results.

	Pb.	*Sn.*	*Sb.*	*Total.*
Magnolia Metal	78.92	5.52	15.21	99.65
	79.34	5.50	15.01	99.85
	78.69	5.93	15.35	99.97
Eagle A	82.30	2.24	15.24	99.78
	82.42	2.13	15.14	99.69
	82.81	2.07	14.73	99.61
Frictionless	84.61	3.08	12.22	99.91
	84.72	3.07	12.11	99.90
	84.27	3.23	12.27	99.77
Mystic	82.40	4.53	13.23	100.16
	82.47	4.40	12.92	99.79
	82.82	4.03	13.13	99.98

III. BABBITT ANALYSIS BY THE METHOD OF H. YOCKEY.

Yockey's method was published in the *Journal of the American Chemical Society* for May, 1906. Below is the method of Yockey as modified. The methods for lead and tin are just as he describes them, but it was found impossible to secure results for antimony by his method, hence the method described below for antimony was substituted. This method proved to be much shorter than Low's method, and the results are quite as satisfactory.

Weigh into a 250 cc. beaker 0.5 grams of the finely divided alloy. Add 20 cc. of nitric acid (sp. g. 1.2) and put on the water-bath. When the alloy is completely decomposed (one or two hours) put in an air bath and evaporate to complete dryness. Bake at 120° for one hour. Remove from the oven, cool, moisten with one cubic centimeter of nitric acid, add 50 cc. of water and boil vigorously for five minutes. Filter off the mixed oxides of tin and antimony, wash with hot water, dry, ignite in a porcelain cru-

cible and add a few drops of strong nitric acid to oxidize any metal reduced while burning the filter paper. Weigh as Sb_2O_4 and SnO_2. Dilute the filtrate from the above to 200 cc., add 10 cc. of ammonium acetate and 5 cc. of dilute acetic acid, heat to incipient boiling and titrate with ammonium molybdate in the usual way.

For antimony weigh out from 0.6 to 0.8 gram of the finely divided alloy into a 500 cc. beaker, add 50 cc. of strong hydrochloric acid, and allow to stand for some time. (In practice it was found to be a good plan to let the alloy stand in cold HCl over night. The disintegration into a fine powder seemed to be so complete that subsequent action by means of $KClO_3$ was readily effected.) Heat to boiling and from time to time add small amounts of solid $KClO_3$ until all is dissolved. Cool, dilute to 500 cc., add a slight excess of potassium iodide crystals and titrate the iodine liberated with $Na_2S_2O_3$ in the usual way. Care should be taken not to add too much KI. If a precipitate forms add HCl until it dissolves.

The percentage of lead present is to be calculated as described in another article. The antimony is to be calculated as shown below. The tin is then to be found by difference from the mixed oxides of tin and antimony. The value of the sodium thiosulphate solution in terms of iodine having been found in connection with other work, its value in terms of antimony had to be found from the reaction equation:

$$SbCl_5 + 2KI = SbCl_3 + 2I + 2KCl$$

Whence 253.7 parts of I are equivalent to 120.2 parts of antimony.

Value in iodine of 1 cc. of the thiosulphate solution	=.xxxxx (*a*)
Value in antimony of 1 cc. of the thiosulphate $(a) \times \frac{120.2}{253.7}$	=.xxxxx (*b*)
Weight of the alloy used	= .xxxx (*c*)
Volume of $Na_2S_2O_3$ used	= .xxxx (*d*)
Antimony found = $(d) \times (b)$	= .xxxx (*e*)
Percentage of antimony = $100 \times (e) \div (c)$	= .xxxx

An attempt was made to use Yockey's method for the estimation of antimony, but after many trials it was abandoned as too difficult for practical purposes. His method secures the reduction of the antimony to the metallic condition after separating it from

the other constituents of the alloy. It comes down in an extremely fine state of division. Filter papers could hardly be made to retain it, and when they did, it spread over the edges of the paper by creeping. Even under the best care the method seemed to give too wide a range of results to be dependable. The following are some of the best results obtained from numerous efforts to apply Mr. Yockey's method:

Alloy taken.	*Antimony found.*	*Percentage.*
1.0062	0.1794	17.83
1.0276	0.0550	5.35
1.0600	0.1114	10.51
1.0312	0.1558	15.11
1.0146	0.0700	6.90

The amount of antimony really present ranged from 9 to 12 per cent as shown by the following figures, which show the results of the analysis of three samples by the method as described.

	Pb.	*Sn.*	*Sb.*	*Total.*
No. 4	85.10	4.95	9.83	99.88
	85.56	4.80	9.37	99.73
	85.75	4.57	9.73	100.05
Monarch Ball Metal	76.94	8.64	14.33	99.91
	76.53	8.52	14.95	100.00
Worn metal from the heating plant of Denison University	79.55	8.88	11.98	100.41
	79.99	8.36	12.05	100.40

Chemical Laboratories,
Denison University,
1908.

A STRATIGRAPHICAL STUDY OF MARY ANN TOWNSHIP, LICKING COUNTY, OHIO.[1]

FRANK CARNEY.

CONTENTS.

[1] This stratigraphical study of Mary Ann Township, as well as that of Perry Township which was published in Vol. xiii, pp. 117–130, plates I–VIII, 1906, of the *Bulletin of the Scientific Laboratories* of Denison University, and which is in-

INTRODUCTION

The exactness with which the formations of a given region may be mapped is conditioned upon several factors: (*a*) Thick mantle rock sometimes so covers the terranes that in the absence of youthful drainage one cannot get good sections. (*b*) Some areas bear heavy glacial drift and consequently present equal difficulties in measuring the formations; this condition may persist even beyond the territory formerly covered by ice, particularly where the drainage from the ice-sheet has made a great deposit of modified drift. (*c*) The attitude of the rocks also plays a part in the outlines produced by weathering: for example, a region that has suffered marked disturbance of an orographic nature will yield locally to agents of degradation, producing good sections for study; whereas in a region where the rocks are generally horizontal, and the erosion cycle was interrupted in early maturity, the conditions are not apt to be favorable to a precise mapping of the rocks. Since the products of rock-decay are shifted chiefly by stream work, it is apparent that the quantitative value of these several conditioning factors is largely a matter of physiography.

PHYSIOGRAPHY

Mary Ann Township, from the standpoint of physiography, involves some complexities. About one-half of the township was glaciated (fig. 1). The prevailing relation of drainage lines to the ice-front encouraged the development of outwash deposits. Some of these valleys are short but carried much water when the ice was contiguous; one valley was mature and for a short distance, may have sloped toward the approaching ice, in which case ponded-water occupied that portion of the valley.

In order to account for the two rock exposures which show good contacts of even part of the formations out-cropping in this township, and to understand why there are no more, it will be necessary

cluded as a part of this report, involving about fifty square miles in the eastern part of Licking County, Ohio, was undertaken at the suggestion of Prof. Charles S. Prosser, whose encouragement through conferences and aid in the field I wish now to acknowledge, as a requirement for a Minor while a graduate student in the Department of Geology at Ohio State University. It is a pleasure also to express my obligation to Mr. C. R. Stauffer, who spent two days with me in this area.

to review briefly what appears to have been the drainage history of the area. One of these cliffs is just north of Mary Ann Furnace, the other is on the western border of the township where Lost Run enters it. In several other places we find exposed ledges, especially on the slopes capped by the Pottsville formation. These two cliffs, it is supposed, mark critical points in the stream contest of the region.

a. An inspection of the topographic sheet (fig. 1) suggests that the oldest drainage line had a general southwest course through the area; this stream had its sources somewhere north or northeast of Mary Ann township. The villages of Hickman and Wilkins' Corners are situated in this valley, which was tributary to the "Newark river," a stream belonging to the reconstructed, southwest flowing drainage investigated by Tight.[2] The cross-section of this valley, for a distance reaching from a point a mile and a half east of Wilkins' Corners to the extreme southwest corner of the township, is a flat mature arc, as revealed by the rock contours. The present direction of stream flow shows that the drainage in this wide part of the valley has been directly reversed. The streams of the western half of the township now unite near Wilkins' Corners; this stream, Wilkins' Run, after flowing eastward for about one and one-half miles through the old, wide valley, follows a narrow rock-walled valley for about three-fourths of a mile, then joins the Rocky Fork. A short distance east of this place of junction we find the narrowest point in the valley of the Rocky Fork; from this point the valley flares both up and down stream; the upstream portion of the present Rocky Fork valley belonged to the "Newark river" system, and was captured by south-flowing drainage.

The ledges of rock along Lost Run also mark a divide which has been cut down by diversion, thus extending the drainage basin of another south-flowing stream.

b. When these drainage changes occurred, and the agent or processes involved, are directly important in the physiography of the area, and indirectly associated with its stratigraphy. Three time-definitions may be considered: (1) incidental to, or subsequent to, Wisconsin glaciation; (2) incidental to Illinoian glaciation, or at sometime during the Illinoian-Wisconsin interval; (3) antedating the Illinoian epoch.

[2] *Professional Paper, No. 13*, U. S. Geol. Surv., p. 18, 1903.

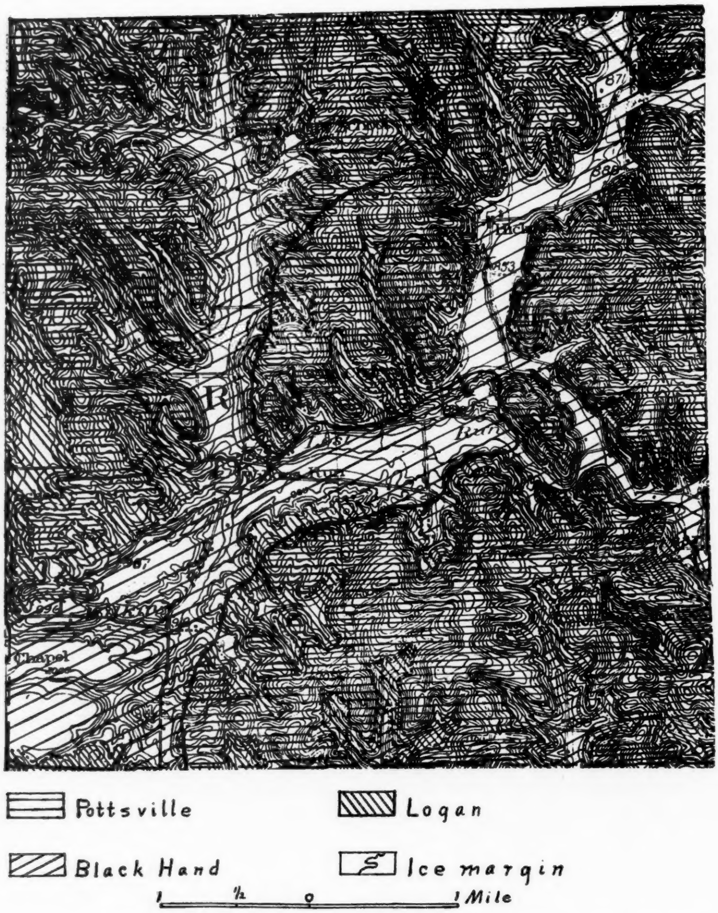

FIG. 1. The base map is a portion of the Newark Quadrangle, advance sheet, kindly supplied by Mr. J. H. Jennings, Geographer, U. S. Geological Survey.

(1) These diversions were not due to outlet-erosion of ponded water marginal to Wisconsin ice; this ice-sheet did not reach the area. If subsequent to this period, head-water capture was the mode of the diversion. Either differential tilting or warping, or the great inequality of volume and load favoring valley-deepening by the streams flowing away from the glaciated region, induced the piracy. In this case the lowered divide segment of the valley should be quite free from alluvium; it should bear no terraces of glacial outwash; it should be narrow and gorge-like.

(2) If the diversion dates from the interval between the two ice-invasions, and was brought about in any of the three methods just mentioned, the chief difference in the appearance of the lowered-divide segment of the valley would be one of age, that is, this segment would show a greater amount of weathering corresponding to the longer time period involved. Whether this segment would bear alluvium of ordinary stream-aggraded material, or of glacial outwash terraces, depends on the relation these valleys bore to the drainage from the Wisconsin ice. As previously stated, it does not seem likely that such drainage existed in the area.

(3) If the diversions were incidental to Illinoian glaciation, then the process of diversion must have involved a cutting down of the outlets of lakes held up in front of the ice. The depth of cutting in the lowered-divide segments of these valleys is so great that these hypothecated ice-front lakes must have existed for a long period. The basins involved in any one of them was so slight that the lakes must have come largely from the melting ice. Lakes lower their outlets slowly because outlet streams are almost entirely free of cutting tools; the great time involved in this outlet-erosion, would insure some evidence of wave-work about the lake shores as well as deposition-work of inflowing streams. The interval of time since the Illinoian glaciation would not remove completely all evidence of such shore-phenomena.

(4) As evidence of a pre-Illinoian date for these diversions we would require (*a*) greater age than described above in the cross-section of the lowered-divide segments of the valleys, (*b*) glacial alluvium present in these segments, (*c*) unmodified drift grading into outwash in, or contiguous to, the captured portions of the valleys, and (*d*) other instances of piracy in the neighboring unglaciated region representing the same movement in drainage adjust-

ment. Each of these four lines of evidence should be clear if the change in the drainage took place before the Illinoian glacial period.

This diversion may indicate an axis of uplift which presumably trended northeast and southwest, and was located westward of this area. Such a differential tilt would stimulate all streams flowing southeast or in a southerly direction, and retard streams flowing to the northwest or in a northerly direction. In consequence of this resulting differential in the cutting power of the streams, the rivers heading south or southeast of this township, encroached upon the drainage north and west. In this manner the divide in the vicinity of Mary Ann Furnace was gradually lowered, resulting in the leading to the southeast of all the drainage that formerly flowed past Wilkins' Corners to the southwest. These same factors, if operating, would account also for the narrow course in Lost Run valley on the western border of the township (fig. 9); with the cutting down of this divide the drainage basin of the southeast flowing streams was considerably enlarged by the accession of area northwest of the township.

While these two cases are the most obvious of the drainage changes in this area, there are also minor variations of slight consequence.

It is my opinion that these diversions took place before any ice came into the area, that is, that this differential tilt or warp and the resulting stream captures were pre-Illinoian.[3] One reason for this opinion is that the narrow parts of these valleys, that is, where the lowered-divides were located, now bear outwash deposits indicating that the divides were low enough, before the ice withdrew from the region, to become partly aggraded; another reason is that if the ice invasion preceded the captures, all the reversed segments of the southwest and west flowing drainage, as above indicated, must have been ponded, the water rising to the height of a col which it in time lowered. We would expect to find about the margins of these former lakes shore phenomena including either constructed beaches, wave-cut cliffs, or deltas. I am unable to find any such evidence of former water bodies. Furthermore the lowered-divide segments of these valleys are flat-bottomed because

[3] On the assumption that the oldest drift in this region is Illinoian in age; this drift may be Kansan.

aggraded with outwash, which has been terraced in places. In cross-section, these segments have a less aged appearance than their flood-plain portions indicate. The two coarse, somewhat resistant formations, the Sharon and the Black Hand, have retarded the usual effects of lateral planation work. The valley dependency of ice which extended eastward from Wilkins' Corners built a moraine ridge[4] across the old valley where it turns northward. This ridge blends into outwash which is terraced for miles southward.

Many other instances of capture, supposed to belong to the same aggressive movement of the south-flowing streams, have been studied, but not much has been published concerning them.

c. (1) Under normal conditions of stream capture the more speedy cutting down of the rock beds insures good exposures for stratigraphical study. The abnormal conditions in the area at hand is that whatever progress the streams thus made in degrading their beds was partially obliterated by the aggradational work of the ice-front drainage. The great distances over which the wash-material from the ice-front has been spread in eastern Licking county, especially in the valleys tributary to the Licking river, is a matter of common knowledge. These flood plains have been lowered some in post-glacial times. That the bed of the Rocky Fork from Mary Ann Furnace southward about a mile and a half is rock is due to rejuvenation. But the rock walls along the stream north of Mary Ann Furnace probably represent the vigorous work of the immediate ice-front drainage. Similar conditions marked a recessional stage of the Wisconsin ice, and developed the cliffs in the valley of Lost Run.

(2) As an agent of erosion, an ice-sheet in its distal portion is especially weak; there is very little evidence that the ice changed the outlines of even the bolder hills in this township. I do not attribute to the ice any over-deepening of valleys, or through-valley work here. Therefore the general effect of glaciation in this region, so far as a study of stratigraphy is concerned, has been to give the uplands a thin mantle of drift, and to bury the flood plains and side walls of the valleys beneath heavy outwash depos-

[4] F. Carney: "Valley Dependencies of the Scioto Illinoian Lobe in Licking County, Ohio," *Journal of Geology*, vol. xv, pp. 492–95, 1907. A picture of this ridge is shown in the *Bulletin*, vol. xiii, p. 138, 1907.

its and moraine terraces. Ice erosion has not lowered the major valleys so as to rejuvenate tributaries; in fact, glaciation in general has prematurely aged the streams of this area. Practically all the valleys bear flood-plain material, and during the post-Wisconsin interval a youthful stage of the erosion cycle has scarcely yet reached this far into the uplands.

STRATIGRAPHY

(*a. Formations*)

Cuyahoga Formation. Along the Rocky Fork, a little east of the eastern border of the township, the Cuyahoga appears, but the interval up stream before reaching the base of Black Hand is covered with alluvium.

Beneath the bridge across the stream at Wilkins' Corners, occur shales which may belong to the Cuyahoga. There is some indefiniteness, however, about this mapping owing to the fact that the upper part of the Cuyahoga may contain "arenaceous and argillaceous shales with some alternating layers of sandstone,"[5] thus resembling the lower part of the Black Hand formation which sometimes contains thin shaly layers.

Aside from these localities, I have not found anywhere in the township, outcrops of the Cuyahoga. That the formation has been deeply incised appears probable from the width of some of the aggraded valleys.

Black Hand Formation. Outcrops of this formation are widely distributed throughout the township. Actual contacts with the Cuyahoga, and with the superjacent Logan formation are rare. At the Lost Run section, the upper contact is well established; here the Black Hand measures 34 feet and 7 inches between Conglomerates I and II; below this I measured 29 feet and 4 inches above the covered flood-plain interval (fig. 2). Its lower part contains no very heavy beds, but towards the top of the section, nearing the horizon of the Allorisma shales or Fucoid layer (fig. 3), the strata thicken and have been used somewhat for building blocks. An unrecorded feature of the Black Hand formation is

[5] C. S. Prosser: "The Waverly Formations of Central Ohio," *The American Geologist*, vol. xxxiv, p. 359, 1904.

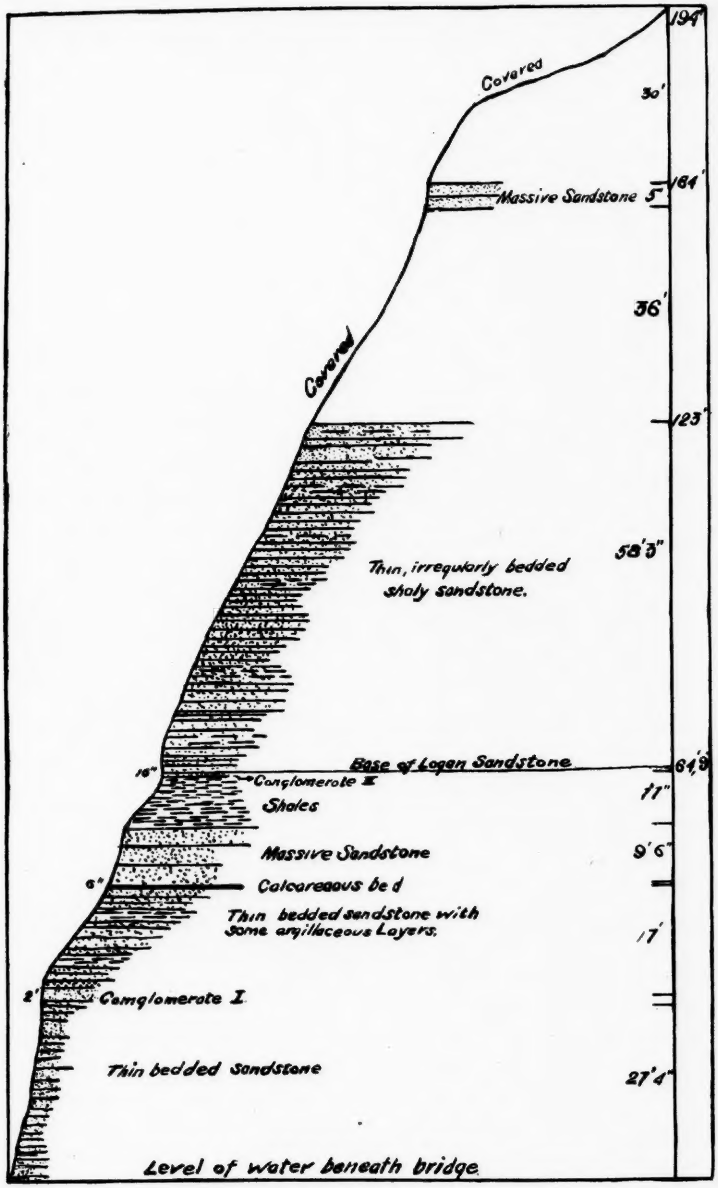

FIG. 2. The Lost Run Section.

the presence of a calcareous layer about 18 feet below Conglomerate II; such a bed, quite fossiliferous, exists in this section.

The most typical outcrop of the Black Hand in the township is the Mary Ann Furnace section (fig. 4). The contact with the Cuyahoga does not exist here, but by a line of levels[6] carried up the stream, it was established that about 31 feet of the formation is covered, slightly more than half being covered by alluvium, the rest by talus. At this section nearly 35 feet of Black Hand is

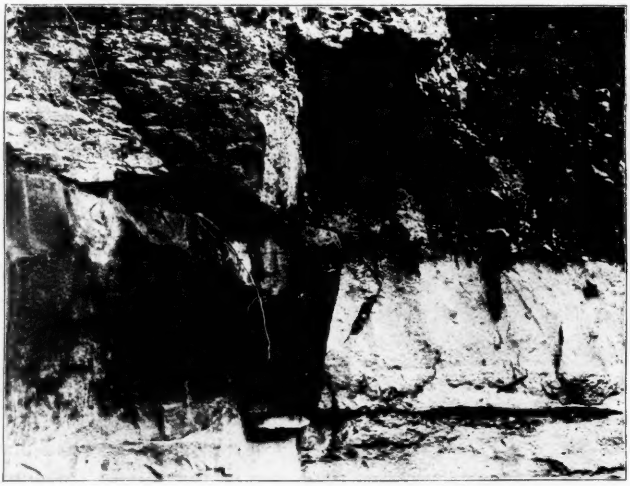

FIG. 3. Shows contact of the *Spirophyton* shales and the massive beds in the upper part of the Black Hand formation in the Lost Run section.

exposed, and, save for about 5 feet at the base of the Logan, the whole consists of quite massive beds. Conglomerate II here is a fairly coarse bed, 10 inches thick. The Allorisma layer was not noted in this section.

Along the principal valleys of the township the Black Hand formation frequently forms a shoulder near the foot of the valley

[6] The author wishes to acknowledge his obligation to C. W. Irwin, B.S. ('08) who wye-leveled the distance between the bridge at Hanover and the point where Wilkins Run joins the Rocky Fork.

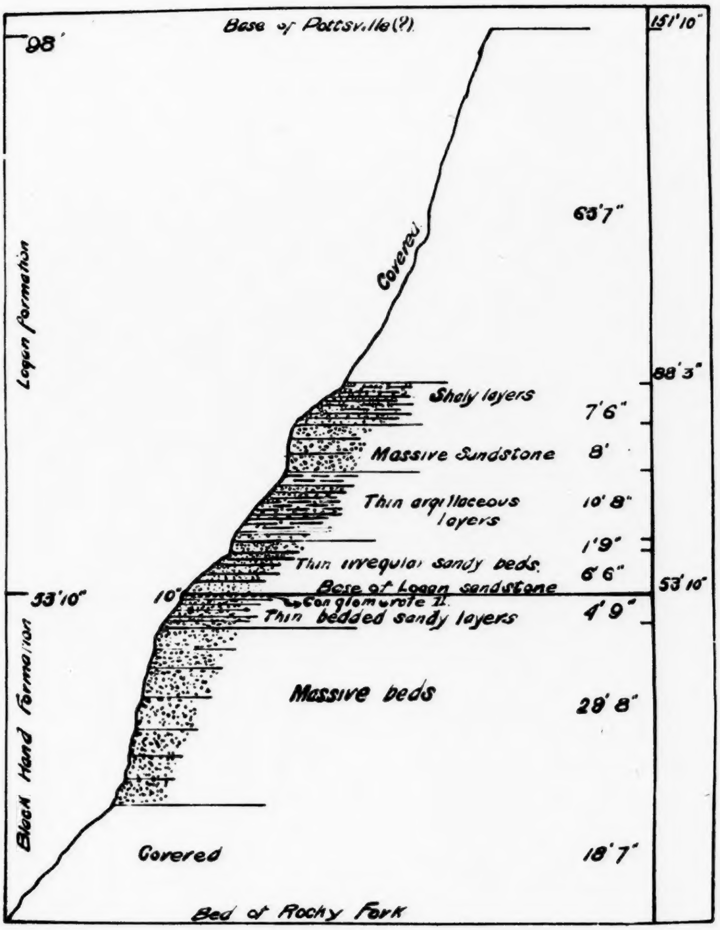

FIG. 4. The Mary Ann Furnace section.

walls; its presence is also indicated by a line of springs, a feature discussed more in detail in another part of this report.

The Black Hand, along both vertical and horizontal lines, is variable in texture, grading from thin fine sandy beds to heavier horizons, frequently quite coarse.

Logan formation. As one ascends from the valley floor along any of the roads leading to the uplands he generally notes first a sharp grade marking the horizon of the Black Hand formation, then gentler slopes which mark the horizon of the Logan sandstone (fig. 11). Wherever studied, I have found the Logan formation to consist chiefly of thin sandy beds, rather fine in texture, alternating with somewhat argillaceous layers. No stratum sufficiently thick or coarse in structure to make itself conspicuous through differential weathering was observed. Nevertheless, in the Mary Ann Furnace section there is one massive layer, a few feet above the bed which has been marked Conglomerate II. There may be an error in the location of the Conglomerate II, in which case the massive layer alluded to belongs to the Black Hand formation. In this section about 34 feet of the Logan is exposed. Above this I have measured approximately 63 feet before coming to the horizon where the Pottsville is on the surface; but this interval of 63 feet is unsatisfactory for a detailed study nor is its contact with the Pottsville sharp.

A study of the slopes associated with this formation throughout the township warrants the conclusion that the Logan, in vertical section, weathers more easily in its upper than in its lower beds. No exposure of the uppermost layers of the formation was found, but from the constant presence of Sharon conglomerate blocks, creeping down over the horizon of the Logan, I infer that the uppermost layers are the least resistant.

In the Lost Run section (fig. 2), about 47 feet of the Logan formation are sufficiently exposed to admit of measurement.

Pottsville Formation. The state geological map[7] gives but one area of the Pennsylvanian formations in this township, i. e., in the northwest corner comprising about one-third its surface. My study of the region shows that at least the Sharon member of the

[7] *Geological Survey of Ohio*, vol. vi, 1888. Edward Orton, Sr. So far as Licking county is concerned, this map follows the work of M. C. Read in his "Report on the Geology of Licking county," *Geological Survey of Ohio*, vol. iii, opposite p. 529, 1878.

Pottsville may be found practically on every hill rising from 150 to 170 feet above the flood-plain of the major drainage lines (fig. 1), while the upper part of the Pottsville shows conspicuously only in the southeast third of the township. At no point was I able to find the contact between the Pottsville and subjacent Logan. A probable reason for this condition has been given above. The thickness of the coarse phase of the Sharon member can be estab-

FIG. 5. The coarse phase of the Sharon, showing cherty fragments and quartzite pebbles.

lished with some degree of satisfaction by locating the fire-clay beds along the highway crossing the hill from Mary Ann Furnace to Wilkins' Corners; several aneroid readings make this measurement approximately 38 feet.

The Sharon wherever studied, is rather coarse, sometimes a conglomerate, locally showing vigorous stream work in the heterogeneous mingling of materials; in a few outcrops the fragments weigh one to four pounds, and are subangular, but mingled with

these slightly worn fragments are quartzitic pebbles (figs. 5, 6) that have long been subject to stream action. The coarsest phase of this conglomerate appears to occupy troughs in the Logan; this inference is based entirely on the vertical range of its outcrops, as no contacts showing the walls of Logan stream channels were found.

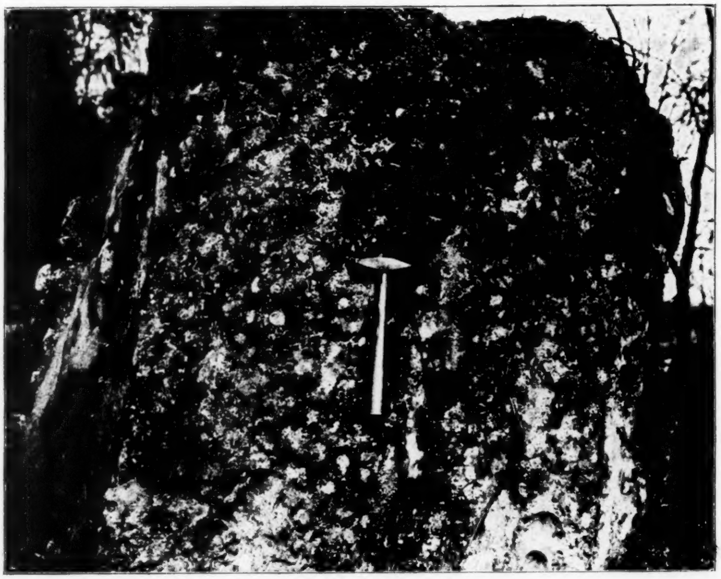

FIG. 6. A Sharon conglomerate block which has worked down the slope over the Logan; the bedding planes are now upright. This and Fig. 5 were taken southwest of Hickman.

(1) In two localities, one about one-half mile southwest of Hickman, and the other on the first sharp grade found in driving from Wilkins' Corners eastward over the hill to Mary Ann Furnace I noted in the Sharon angular fossiliferous cherty blocks. The fauna collected from these has been turned over to Mr. W. C. Morse, who is working on the Maxville. The fossiliferous content of the Sharon conglomerate was observed years ago by Read but I have been unable to learn that he succeeded in tracing the frag-

ments; he states[8] that the fossils were "identified by Mr. Meek as belonging to the carboniferous formation." If the fauna is found to be Maxville, then we can understand how the degradation of this horizon in early Pottsville time might account for its presence in the Sharon. A very careful search has been made both in this township and in Perry township directly east, but no Maxville limestone was found. This fossil content of the Sharon conglomerate affords an interesting problem.

(2) About two miles west of Mary Ann Furnace during the early seventies, a thin vein of coal was worked on the "Baker" place; the same horizon apparently was also worked on the road leading southwest across this high area. At this latter place the coal vein was buried by only a few feet. This coal horizon apparently had a very irregular horizontal distribution; in an outcrop between the two localities above mentioned, its presence is only suggested by a "blossom."

In one more place there is evidence of a former shallow coal working. This is at the top of the grade west of Mary Ann Furnace reached by taking the first road bearing to the north, and is near the corner made by this highway meeting one from the south. Just west of the corner reddish shale is found subjacent to fireclay; a few rods farther, we find more of this clay and a "blossom" above it.

On the supposition that the Logan formation in this area is not thicker than in the Mary Ann Furnace section, i. e., about 100 feet it follows that we have here 160 feet of Pottsville; in the absence of a definite contact between the Sharon and Logan, only this method remains for obtaining, even approximately, the thickness of the Pottsville.

b. Sedimentation

(1) The outlines of former land areas, and their altitude, may be indefinitely inferred from a study of the rocks. The constancy in the thickness of a given formation; a variation in its texture, horizontally and vertically; its structural peculiarities, whether genetic or imposed later, if any; its life, whether marine, littoral, or continental, whether prolific, sparse, or stunted; all tend to defining the continents of the past. Furthermore, the constancy or

[8] *Geological Survey of Ohio*, vol. iii, pp. 545–46, 1878.

inconstancy of these details as we pass vertically through a succession of formations shows whether the land area furnishing the sediments is gradually rising from the sea or is being transgressed by it, and indicates also the stage of the erosion-cycle as well as the general climatic conditions. But the organisms of the past periods, and equally too of the present, constitute the vitalizing fact of geologic studies, and at once furnish the basis for geography, either past or present.

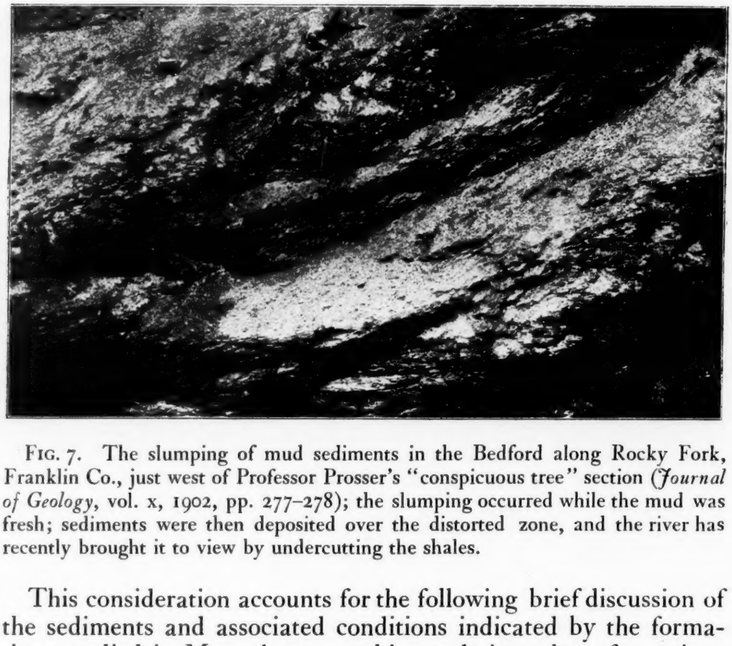

FIG. 7. The slumping of mud sediments in the Bedford along Rocky Fork, Franklin Co., just west of Professor Prosser's "conspicuous tree" section (*Journal of Geology*, vol. x, 1902, pp. 277–278); the slumping occurred while the mud was fresh; sediments were then deposited over the distorted zone, and the river has recently brought it to view by undercutting the shales.

This consideration accounts for the following brief discussion of the sediments and associated conditions indicated by the formations studied in Mary Ann township; and since these formations belong to the Mississippian and Pennsylvanian periods, I have included in the discussion all of the former period as exhibited in central Ohio.

(2) *The Bedford Shale* formation save in its uppermost few feet is a fairly homogeneous mud deposit. It varies somewhat from place to place in color, the range being from chocolate red to a blackish gray. The texture of this formation suggests off-

shore deposits, and its thickness indicates a slowly transgressing sea, thus maintaining the depth of water that would assure freedom from the coarser terrigenous deposits (fig. 7). The nature of the sediment, furthermore, indicates a sea transgressing upon a land area that had long withstood erosion, a region already mantled with deposits of residual decay. Where, however, the Bedford shows some arenaceous layers inter-stratified (fig. 8), there is evidence of broad river deltas reaching out into the epi-continental zone. Here the irregularity of sedimentation occasioned by the seasonal or by longer cyclic periods of unusual water supply would

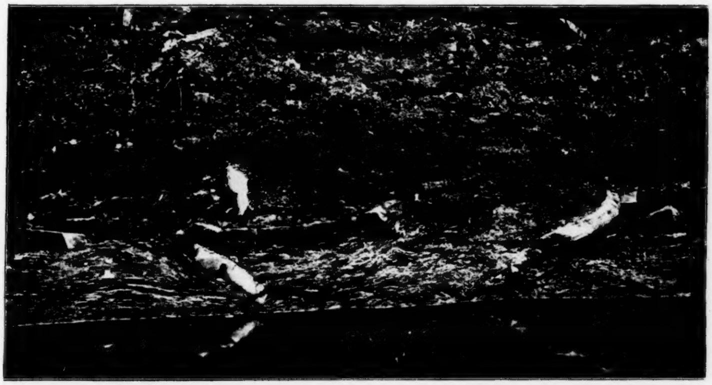

FIG. 8. Disturbed zone at the base of the Berea along Rocky river, Franklin county, described by Professor Prosser (*The American Geologist*, vol. xxxiv, 1904, p. 340, footnote).

extend the coarser sediments temporarily over areas where hitherto only the finer muds were being deposited.

Berea Formation. This series of thin bedded to slightly massive gritty layers above, below to arenaceous shales, about 37 feet in thickness,[9] illustrates rippling perhaps as no other horizon in the state displays the phenomenon. Along the Rocky Fork, up stream from the areas shown in figs. 7, 8, these sandy layers, for a vertical distance of 6 to 8 feet, consist of beautifully rippled beds averaging about two inches in thickness. Such a vertical range of conditions of sedimentation, usually interpreted as representing

[9] C. S. Prosser: *The American Geologist*, vol. xxxiv, p. 340, 1904, footnote.

shallow water, must imply a subsidence of the area receiving the sediments synchronous with the filling produced by the deposits. This conclusion is based on the assumption that such a uniform condition of ripple marks persisting through a considerable vertical range implies a constancy of sedimentation factors. Towards the upper part of the Berea, however, the beds thicken, becoming more sandy, thus suggestive of littoral sedimentation.

Sunbury Formation. This horizon of rocks consists chiefly of shales locally arenaceous, but in the main, black in color and bearing a considerable fauna. Both the fauna and the lithological aspect of the formation indicate marine sedimentation. On this principle, then, the water area in which the next older formation, the Berea, was laid down, continued to transgress the land, thus maintaining a horizon of marine deposition.

Cuyahoga Formation. This formation consists of shales and sandstones, the upper boundary of which was for some time given as Conglomerate I.[10] Later studies,[11] however, have shown that this conglomerate horizon is not persistent, and furthermore, that even where found it overlies beds that do not have the Cuyahoga characteristics. So far, however, as the process of sedimentation involved in the Cuyahoga beds admit of interpretation, it is evident that the quick transition frequently noted from fine to coarse textured layers probably indicates a somewhat static relationship of land and water which would result in the coarser sediments locally reaching out over mud deposits. This supposition accounts for the transition from shale to an arenaceous or even a conglomerate horizon. When, however, mud deposits follow, in the vertical succession, the sandstone or argillaceous shale, which is the prevailing relationship in the Cuyahoga inasmuch as it contains more shale than any other textured rock, it is surmised that the predominating tendency of the water body was transgressive. I feel nevertheless that a closer mapping of the Cuyahoga and the conglomerate horizon by which the top of the formation was formerly fixed will reveal much horizontal variation, and that the meaning of this inconstancy is a closely balanced relationship during the early and late Cuyahoga times between the rate of deposition and the rate of transgression by the sea.

[10] C. L. Herrick: *Bull. Denison University*, vol. iii, p. 26, 1888.
[11] C. S. Prosser: *The American Geologist*, vol. xxxiv, p. 359, 1904.

Black Hand Formation. This horizon of rocks overlying the Cuyahoga is generally called a conglomerate. The conglomerate phase is indeed remarkably developed in many localities; on the other hand the formation consists locally of fine sand and even of argillaceous sands. From the standpoint of methods of sedimentation the striking feature of the Black Hand is its thickness (fig. 13). We note, not infrequently, ledges often about 100 feet thick where it shows very little irregularity in texture. This constancy of shallow water or of littoral sediments implies a sustained relationship of land and water brought about through the rate of deposition balancing the rate of land subsidence or of transgression by the sea. Where, however, we find this formation interrupted vertically by beds somewhat coarse and often conglomeratic there is evidence of more vigorous erosion, or of tidal assortment combined with current scour, resulting in the localization of coarser deposits. Accordingly the conglomerate beds of the Black Hand are not consistent in horizontal development. For this reason we are inclined to favor the wave and current rather than the stream-erosion explanation for these coarser beds.

The Logan Formation. This formation consists of sandstone, somewhat clayey in character, with now and then a thin layer of shaly sediments. The prevailing condition of sedimentation during this period is certainly not clear. The irregularity of the formation in horizontal extension, however, gives some suggestion. Furthermore, the general thickness of its beds leads to the same conclusion, namely, a transgressing sea following up rivers already mature in their drainage-cycle-position, with the rate of deposition lagging considerably behind the rate of transgression. The general absence of mud deposits and the fine texture of the sandstone in this formation both indicate a nearby source of sediments, presumably the working over of those last developed and of continental sediments. Further evidence leading to this same conclusion is found in Conglomerate II, a persistent coarse horizon marking the boundary line between the Black Hand and the Logan. This conglomerate is widespread but not thick, its maximum depth usually being less than two feet. This relationship is suggestive of transgressive deposits marking a slow growth of a sea over the land in the gradually deepening of which water-body the Logan sandstones were laid down.

The Pottsville Formation. The Sharon member of this forma-

tion is prevailingly coarse; locally it is exceedingly coarse. A variation along horizontal lines is the most striking feature of the Sharon. The transition laterally from fine, even-textured sandstone, to irregularly bedded conglomerate masses ranging from quartzite pebbles to units 4 or 5 inches or even larger of siliceous fragments, was long ago noted by geologists in Ohio. The evidence of regressive continental sedimentation in the Sharon is quite conclusive.[12] Terrestrial streams here have followed a retreating shore line, their flood plain and alluvial fan deposits being indicated now by the coarser phases just alluded to. Such a transportation of river deposits would be witnessed in a tilt or warp of an ocean-border tract, the movement progressing inland. Thus in the littoral zone finer sediments would accumulate, irregular in horizontal distribution because of vigorous streams, a condition less favorable to fauna; these sediments, the Logan, would suffer erosion locally, and in the channels thus made later sediments, the Pottsville, were deposited.

The patches of fire-clay and of coals found in the upper Sharon and later Pottsville indicate a balanced condition between erosion and deposition which insured a wide littoral zone and the development inland of extensive flood-plains.

c. Geographic Influences Arising from this Stratigraphy.[13]

In the arid southwest parts of the United States, the crude water signs of the Indians have often pointed the white man to a spring. The government topographic maps covering sections of this region of sparse rainfall give the location of many springs. Throughout the longer-known and more-traveled desert areas of the world, the few oases have fixed the routes taken by caravans. Numerous books are available detailing facts that bear on the geographic influence of springs in arid climates. But into whatever land man has gone, humid as well as arid, springs have had a part in his activities. So far as America is concerned, I am not aware that a quantitative

[12] D. White: *Bull. Geolog. Soc. Am.*, vol. xv, p. 279, 1904, urges that a transgressing sea was associated with the deposition of the Pottsville sediments.

[13] The remainder of this paper is reprinted from *The Popular Science Monthly*, vol. lxxii, pp. 503–11, 1908, where it appeared under the title, "Springs as a Geographic Influence in Humid Climates."

study of the influence of springs in humid regions has been undertaken.

(1) While mapping the stratigraphy of an area of approximately 25 square miles in central Ohio, where the annual precipitation is about 40 inches, the influence exercised by springs was given particular attention. In this area the upper formations of the Mississippian, and the lower of the Pennsylvanian periods come to the surface. The vertical series of rocks involves two

FIG. 9. Looking up-stream through the narrow, former col, part of Lost Run. The section shown in Fig. 2 was measured beneath the trees standing on top of the cliff in the middle distance. A primitive log house marks the location of a constant spring.

horizons of coarse clastic sediments, the Black Hand of the earlier period, and the Sharon member of the Pottsville, which is the lowest formation of the later period. The Black Hand overlies the Cuyahoga, which in central Ohio "is composed largely of bluish and grayish shales and buff sandstones."[14] Subjacent to the Sharon is the Logan formation consisting chiefly of "buff arenaceous shales to thin bedded sandstones."[15] The Black Hand is a mas-

[14] Charles S. Prosser: *Journal of Geology*, vol. ix, p. 220, 1901.
[15] *Ibid.*, p. 231.

sive sandstone, locally conglomeratic; the Sharon is less massive, and locally coarser; this characterization of these two formations applies specifically to the area studied. While neither of these sandstone formations overlies impervious beds, yet in themselves they are variable in texture and structure, and the region is so maturely dissected (fig. 15), that conditions are very favorable to the development of springs. Furthermore, the Logan also contains beds that are water bearing.

(2) The early settler in agricultural lands found a spring, if possible, and then built his log house. Others coming into the

FIG. 10. The iron content of this Sharon rock induces the "honeycomb" effects in weathering, and also makes the springs less desirable.

region made similar locations. Settlement generally moved along streams, since in the absence of roads valleys are more accessible. If the valley has been developed in water-bearing formations, which are not much tilted, springs border the bottom land on either side. Both topographic convenience and the presence of water tended to confine the earliest habitations to the valleys. Later settlers spread over the intervalley areas, building their houses in proximity to springs.

Primarily the highways lead from house to house; eventually, however, several factors become operative before the roads are permanently fixed. In the case of a valley having a commodious

FIG. 11. The gentle slopes of the Logan formation afford good farms, but few springs for dwellings. Twice as many houses are found along the lower contours of the Black Hand formation where water is plentiful.

flood-plain, but not extensive enough to warrant the maintenance of roads on each side, the slope bearing the better springs was normally the decisive factor; the homes on the opposite side would be approached by fords and lanes, or by only the latter if located near a transverse highway. In the uplands the permanent lines of traffic appear to take courses that will accommodate the greatest number without making too great sacrifice in distance; even then some dwellings are isolated. The isolation may continue but one

FIG. 12. The tiny rill of a spring that has already developed a small basin in the Black Hand formation.

generation, or until the desire to live on the highway overcomes the convenience of water and the associations of the hearth; the latter factors have prevailed wherever we see an isolated frame house, whereas a deserted log cabin means the dominancy of the former.

Moreover, the intervalley highways sometimes exhibit an economic influence. When the area is heavily timbered, and lumbering rather than agriculture is the initial occupation, the roads made

in connection with logging and milling may become permanent. For example: North of Wilkins' Corners (fig. 1) the second highway leading west ascends about 160 feet in one-half mile; this road parallels a valley a few rods to the left, where the same horizontal distance involves only half the grade; the original highway did follow the valley, connecting the two houses. But log-haulers from the wooded upland located their main road where it would command as much of the area as possible, approaching it

FIG. 13. The Black Hand formation is generally a coarse, irregularly bedded sandstone, yielding a copious supply of spring water.

by spurs along contours. This traffic fixed the road where it is, though it has never led directly to a dwelling; property complications diverted the second house up the valley to it, the original roadway being abandoned. A similar influence in highway location due to mining operations is seen one and one-half miles west of Mary Ann Furnace in the road trending southwest from the one leading to Wilkins' Corners. Some 50 years ago a vein of coal on this slope was worked for local use, and was approached from the west, thus opening a highway that has served little use since.

It is evident also that so far as the intervalley roads are concerned, the topographic factor made slight appeal to the locating

engineers, an ox-team and its driver. If the most direct line between houses, i.e., between springs, crossed a sharp hill, the highway went directly over rather than follow a contour, or take even a gentler, if slightly longer, grade. I have noted several places where in the past decade these sharp grades have been

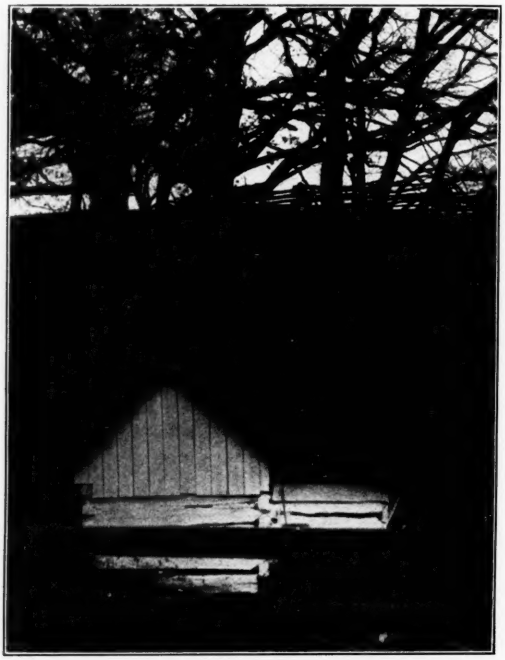

FIG. 14. Sawed shingles and a few boards are used in lengthening the years of service of this rough-hewn log spring house.

removed by a detour, but two generations had dragged themselves wearily over the hill.

(3) The convenience of good water, or of rich bottom lands in the valleys, factors that would seem to have much weight with the early settler in choosing a location, is of secondary importance when opposed to an inherited topographic proclivity. A man reared among hills, however barren, has a latent tendency to plant

FIG. 15. A mature stage of erosion is a condition favorable to numerous springs.

his new home in similar topography. This bias, developed through environment, whether inherited or acquired by the individual, is illustrated in the choice of lands made by Welsh immigrants who came into Licking county, Ohio, early last century; they passed by thousands of acres of lowlands, the richest in the state, and selected farms in a rugged portion of the county, still owned by their descendants, and even now designated "The Welsh Hills."

(4) But in the region to which special study was given, the geographic influence of springs is obvious. There are 203 houses in the township, 148 of which are built at springs; some of the 55 using wells formerly depended on springs. Both the horizontal and vertical distribution of these dwellings is largely a matter of stratigraphy of which the springs are a manifestation. It should be noted, however, that the localization of houses near Mary Ann Furnace is due to the fact that over sixty years ago iron ore, found in the neighboring hills, was reduced here; stoves also were manufactured at this place. The furnace was destroyed in 1853, but the houses are still in use.

(a) Over 50 per cent of the dwellings with springs are in the horizon of the Black Hand formation (fig. 13), which borders the flood-plains of all the valleys, a distribution made possible because the formation has an eastern dip of about 25 feet per mile. The springs in the Black Hand are numerous and copious (fig. 12), partly because of the thickness and texture of the formation, also because of its subjacency to horizons that carry water freely.

(b) In the Logan formation, I have mapped 30 houses with springs. There is doubt concerning a few of these, an indefiniteness occasioned by the absence of contacts. The Logan sediments suffered erosion contemporaneously with Pottsville sedimentation; furthermore, the Logan, in comparison with its contact formations, the Black Hand and the Sharon, weathers easily, producing gentle slopes. These two conditions make it doubtful about the exact horizon of a spring near either the top or the base of the Logan.

(c) Slightly less than 17 per cent of the houses with springs are found in the Sharon. The areal extent of all the exposed formations diminishes vertically, hence the number and the volume of the springs decrease; the value of the land for farming also decreases with altitude. A further fact concerning the springs of the Sharon is their content of iron, making them less desirable than springs in either of the lower formations (fig. 10).

The township contains no extensive areas of outcropping coal measure or Pennsylvanian formations, save in the south central portion; elsewhere disintegration has left only outliers. In the area west of Mary Ann Furnace, covering several square miles, and another along the eastern border of the township, there are eighteen houses, three of which, now occupied, have springs. For the entire township, the average number of houses per square mile is about eight; for the horizon of the coal measures, it is less than two. That springs are rare is not the sole cause for the discrepancy; the bleakness of the upland, and the unproductiveness of the soil are contributory factors.

About 10 per cent of the homes with springs are built on glacial deposits. The drift is localized chiefly in the valleys. The ice-sheet covered approximately two-fifths of the township, but left scarcely a veneer of drift on the intervalley areas. While fourteen springs have been mapped as belonging to the drift, it is quite probable that a good fraction of these are fed by water courses from the Black Hand formation. Of the wells noted, 56 per cent are in glacial deposits.

Still another evidence of the influence due to springs is seen in the fact that of the eight deserted houses in the townships one is in the Black Hand formation, one in the Logan and six in the Coal-Measures, the horizon practically without springs. It is noted also that 22 per cent of the dwellings are off highways, an isolation due entirely to springs. Furthermore, dairying has always been carried on in this region (fig. 14) because in the summer season the springs furnish cool water for handling milk.

SIGNIFICANCE OF DRAINAGE CHANGES NEAR GRANVILLE, OHIO[1]

E. R. Scheffel

OUTLINE

Introduction

Physiography of Area and Nature of Problem

This paper will endeavor to prove by the intensive investigation of a limited area a dynamic phenomenon which has probably influenced much of the drainage history of Ohio. The area considered includes practically the whole of Licking county, with the village of Granville as the approximate center and offering in its physiographic environment the most decisive proofs for the contentions made.

"Licking county lies near the center of Ohio and its present drainage is by the Licking river, which is formed at Newark by

[1] Work done under the direction of Prof. Frank Carney, Denison University, as partial requirement for the Master's Degree.

the confluence of three streams, the North and South Forks and Raccoon creek. These streams form a hydrographical basin which is very nearly coextensive with the county lines."[2] To the west of the headwater portions of the North and South forks, narrowings followed by decided flarings are noted. By correlating these narrowings and following the most unbroken line of high rock altitudes the conclusion is reached that a former divide passed through Granville[3] in an approximately north-south direction.

DRAINAGE CHANGES

Before considering the cause of the diversions in this area it may be advisable to give a general discussion of the subject, drainage changes.

The causes for such changes may be somewhat arbitrarily divided into three heads,[4] though it is quite possible for two or all to be inextricably associated. These causes are piracy, glaciation, and diastrophism. Others, less important and more localized, will be omitted.[5]

1. *Piracy.*[6] This term is applied when one stream "steals"[7] another. Primarily piracy is resultant from the more rapid headwater growth and deeper cutting of the pirate stream as compared with the robbed or beheaded drainage line. Davis gives a dramatic account of the contest for supremacy between the east and west flowing streams draining the Blue Ridge.[8] The entire Appalachian system is also cited as witnessing many such contests.

Though these contests may not represent in every instance typical cases of piracy, still, in a broad sense, when by the greater relative growth of one stream its divide migrates, thus lessening the drainage area of another, the first has in reality robbed the second.

[2] W. G. Tight: *Bull. Sci. Lab. Denison Univ.*, vol. viii, part ii, p. 36, 1894.

[3] F. Leverett: *Glacial Formations of the Erie and Ohio Basins*, Monograph xli, U. S. Geological Survey, p. 160, 1902.

[4] *Ibid.*, pp. 196–200.

[5] G. D. Hubbard: *The Ohio Naturalist*, vol. viii, p. 349, 1908. A. C. Lane: *Bulletin of the Geological Society of America*, vol. x, p. 12, 1899.

[6] I. Bowman: *Journal of Geology*, vol. xii pp. 326–334, 1904.

[7] R. D. Salisbury: *Physiography*, p. 176, 1907.

[8] W. M. Davis: *Bulletin of the Geographical Society of Philadelphia*, vol. iii, pp. 213–244, 1903.

For simplicity the causes inducing piracy will be considered with glacial and diastrophic forces as quiescent. Three may be named: Topography, stratigraphy, rainfall. Each of these will be considered alone, disregarding the other factors.

Topography. Of two drainage systems separated by a divide, the one lying on the steeper slope has a decided advantange. The impetus given its waters permits it to cut more deeply and rapidly than its opponent. The divide consequently migrates; the feeding areas of the weaker stream are gradually gained and more or less of its headwater drainage captured by the stronger. The most striking cases of piracy occur when the two contending major lines flow approximately parallel. This may conceivably permit the sudden capture of almost the whole of the weaker system. When the major streams flow in opposite directions from the divide separating them,[9] as in the Blue Ridge, the ground is sharply contested and the diversion of drainage less evident.

Piracy may occur between systems of drainage or within a system. The same laws are operative in either case.

Stratigraphy. Differences of structure and dip in the strata over which they flow may give one of two streams a decided advantage over the other. Thinly bedded strata offer less resistance to weathering, corrasion and corrosion than do heavily bedded strata. The direction of outcrop relative to stream flow is also a factor in erosion. Chemical composition and structure, whether unmetamorphosed sedimentary rock or igneus or metamorphic rock, must also be considered.

By advantageous combinations of the above one stream may cut its channel more rapidly and eat headward faster than its neighbor, thus securing substantially the same conditions as in the case of the stream with steeper slope.

Rainfall. It is evident that, all other conditions being equal, of two opposing streams the one in the area of heaviest rainfall would have the greatest advantage. There are many instances where a divide obstructs the prevailing winds causing the precipitation of nearly all their excess moisture on the windward side. In such areas it is evident that the streams draining the territories of greatest rainfall would ultimately gain an advantage similar to that favored by topography or stratification.

[9] F. S. Mills: *Journal of Geology*, vol. xi, pp. 670–678, 1903.

2. *Glaciation.*[10] This has been considered the principle factor in changing the drainage over considerable areas. Tight[11] ascribes the reversals in the drainage of Ohio to this cause. Leverett inclines to the same explanation for this and other areas. Leverett has shown a tendency, however, to admit the possibility of another explanation for changes in glaciated areas.[12] Carney,[13] particularly, has suggested a theory of preglacial diversion for certain Ohio streams.

Glaciation may effect drainage in various ways, i. e., by planing topography and by eroding divides.

Planing Topography. This may be accomplished by the erosive action of a glacier combined with its later passivity with resultant heavy aggradation. This may effect a changed drainage having the same general course as the preglacial, or the débris filling may take a slope at variance to the original valley bottoms necessitating a very different and perhaps reverse course.

Eroding Divides.[14] Cols may be cut directly by the corrasive action of glaciers. Again, a valley may be dammed by a morainal deposit[15] necessitating outflow of the drainage in a new direction, sometimes over rock divides. Perhaps the most commonly recognized cause is damming[16] of the headwater areas by the ice-front. In such instances the water is ponded between the ice and divide, and is forced to seek an outlet over the lowest point in the latter. Eventually a deep channel or channels may be cut through it. The deposition of drift in such a lake would normally be heaviest near the ice, with the possible result of a change in the slope of the bottom, downward toward the col, leaving on the retreat of the ice a reversed drainage. Sometimes glacially formed lakes

[10] R. S. Tarr: *Physical Geography of New York*, pp. 154–184, 1902. G. D. Hubbard: *Ohio Naturalist*, vol. viii, pp. 349–355, 1908. W. G. Tight, J. A. Bownocker, J. H. Todd, and Gerard Fowke: *Special Paper No.* 3, "The Preglacial Drainage of O.," O. State Acad. of Sc.

[11] W. G. Tight: *Bull Sci. Lab., Denison Univ.*, vol. viii, part ii, pp. 35–61, 1894.

[12] *Bull. Sc. Lab., Denison Univ.*, vol. ix, part ii, p. 21, 1897. *Monograph* xli, p. 199. G. C. Matson: *Jour. of Geol.*, vol. xii, p. 139, 1904.

[13] *Bull Sc. Lab., Denison Univ.*, vol. xiii, p. 151, 1907.

[14] F. Carney: *American Journal of Science*, vol. xxv, pp. 217–223, 1908. T. L. Watson: *Univ. of State of N. Y., State Museum Report* (No. 51), vol. i, p. 171–2, 1899. H. L. Fairchild: *Bull. Geol. Soc. Am.*, vol. x, pp. 27–68, 1899.

[15] *Ibid.*, vol. vi, pp. 354–5, 1895.

[16] G. K. Gilbert: *Bull. Geol. Soc. Am.*, vol. iii, p. 286, 1897.

survive the withdrawal of the ice, at times being confined in valleys between two moraines.[17]

While the theory of the erosion of divides is quite plausible it seems not improbable that this may have been pushed too far. The overflowing water would be deprived of nearly all its cutting tools and would consequently be dependent almost entirely on corrosion for dissolving down its spillway. The time necessary for such a process would seem greater in certain instances[18] than could be granted for the favorable position of the ice-front.

Changes of drainage by glaciation may be ephemeral, lasting only through the period when immediately affected by the ice, or such changes may be of great permanency, outlasting indefinitely the period of glaciation. All degrees of endurance may be found between the two extremes.

3. *Diastrophism.* This term includes all crustal movements. Diastrophism is the most potent and far-reaching of all the causes inducing drainage changes. In many examples explained by piracy or glaciation it is probably an unseen factor. Slight movements are difficult to determine, particularly when inland, and for this reason have not been accorded their full share of influence.

M. S. Campbell has formulated the theoretical effects of land movements occurring under ideal conditions.[19] He also describes specific instances of drainage changes and applies these theories to them.[20] His "Law of the Migration of Divides" is a brief summary of the theoretical side of the question. It is as follows:

"When local radial movements occur in any region the stream divides in that area will tend to migrate;[21] the direction in which they move will be determined by the character of the crustal movement; and the extent of the migration will depend upon the amount of movement and the local obstacles which the streams may encounter. If the movement is upward the divide will tend to migrate toward the axis of uplift; and if the movement continues

[17] R. D. Salisbury: *Loc. cit.*, p. 280.

[18] F. W. Harmer: *Quarterly Journal of the Geological Society* (London), vol. lxiii, pp. 470–514, 1907.

[19] *Journal of Geology*, vol. iv, pp. 567–581, 1896.

[20] *Ibid.*, pp. 657–678. See also L. G. Westgate, *American Geologist*, vol. xi, pp. 245–260, 1893.

[21] A phase of the migration of divides consequent on faulting by W. S. T. Smith, *Journal of Geology*, vol. v, pp. 809–812, 1897.

long enough, and other conditions are favorable, it will reach the axial line and there remain. If the axis coincides with a divide already established, it will hold the latter stationary unless some stronger influence causes it to migrate.

"If the movement is one of subsidence the divide will tend to migrate away from its axis; and will continue in that direction until the streams attain a condition of equilibrium. The migration of the divide away from the axis of depression generally results in the formation of a stream along the axial line; and the direction in which it flows will depend, in a great measure, upon the pitch of the axis of the fold."

A peculiar phase of stream diversion, evidently not in the literature but theoretically possible, may be considered. A slight differential movement resulting in a steepened slope on one side of a divide and a lessened slope on the other, would encourage headwater cutting on the first mentioned side and aggradation on the second. In time the divide would be cut through, the stronger stream gradually diverting the weaker by cutting back into its aggraded bed. Other theories have always implied a backward cutting through solid rock under such conditions, but the very movement which induces this cutting on the one side encourages aggradation or at least the accumulation in situ of the products of erosion on the other, thus giving the proposed theory a strong basis for support.

Of the local movements in the United States those in the Great Lakes and New England areas have been given considerable attention.[22]

Tilting is probably never the only factor entering into drainage changes; rock structure and dip, glaciation, the revolution of the earth, etc., may have greater or lesser shares in the responsibility.

DETAILED DISCUSSION OF LICKING COUNTY STREAMS

Raccoon Creek. This stream will be taken as a type and a minute discussion of it given to prove the change of drainage and

[22] J. B. Woodworth: Bulletin 84, *New York State Museum*, p. 66, 1905. A. W. Grabau: *Ibid.*, (no. 45), vol. ix, pp. 55–66, 1901. G. K. Gilbert: U. S. Geol. Surv., *Annual Report* no. 18, pp. 601–47, 1898. G. K. Gilbert: *Smithsonian Report*, pp. 237–244, 1890. Also "Preglacial Valleys of the Mississippi," by F. Leverett, *Journal of Geology*, vol. iii, p. 763, 1895.

its cause. Raccoon creek rises in the west by northwest part of Licking county, flows southeast to Alexandria and then almost due east to its junction with the South Fork of the Licking at Newark. The old topography of the headwater area has been so completely masked and smoothed by a filling of glacial débris that interpretation of the preglacial history is difficult. This interpretation must depend largely on the evidence of the less obscured area downstream. Beginning near Alexandria the drift filling slopes sharply eastward and the great width of the valley is revealed for several miles, until near Granville where it suddenly narrows, passing between rock walls. The appearance of this valley suggests a large amphitheater opening eastward: to the west, a sloping drift surface; southeast and east, except at the gap noted, rock walls of the Waverly Series. The northern wall consists for apparently several miles of a drift divide separating this valley from a similar one constituting the headwater area of Brushy Fork. The length of this drift divide, considered in connection with the narrow rock-walled outlet to the east, is strong evidence that a former stream headed north of the present divide and following the large valley already mentioned passed westward through Alexandria. For convenience this old drainage line may be called the Alexandria river. (Fig. 1.)

The narrowing in the Raccoon continues for about a quarter of a mile east where the junction with an "Old" north-south tributary valley[23] permits a decided southward flaring. The east wall of this tributary valley reaches out as a spur into the valley of the Raccoon, producing its minimum width. The constriction is further emphasized by the presence of a glacially worn rock hill known as Sugar Loaf, lying in the valley slightly northwest of the spur. East of Sugar Loaf about a third of a mile is a similar but larger rock hill, "Mount Parnassus." This physiography suggests that a divide shaped like a reversed *S* once existed at this point; the two isolated rock hills being the remaining fragments of the outermost curves of the *S*. These two points, it may be noted, correspond very nearly with the east-west limits of the village of Granville. (Fig. 2.)

From this divide area eastward about three miles the valley again widens, the greater width being principally due to the numer-

[23] E. R. Sheffel: *Bull. Sci. Lab., Denison Univ.*, vol. xiii, p. 154, 1907.

ous tributaries, particularly those from the north. Just before the junction of the valley of the Raccoon with that of the Licking rivers another narrowing occurs. The relative widths and lengths of these described portions of the Raccoon may best be obtained by consulting the contour map, fig. 1.

Rock Floor. The entire length of the valley from Alexandria east to its junction with the Licking has been shown to be filled

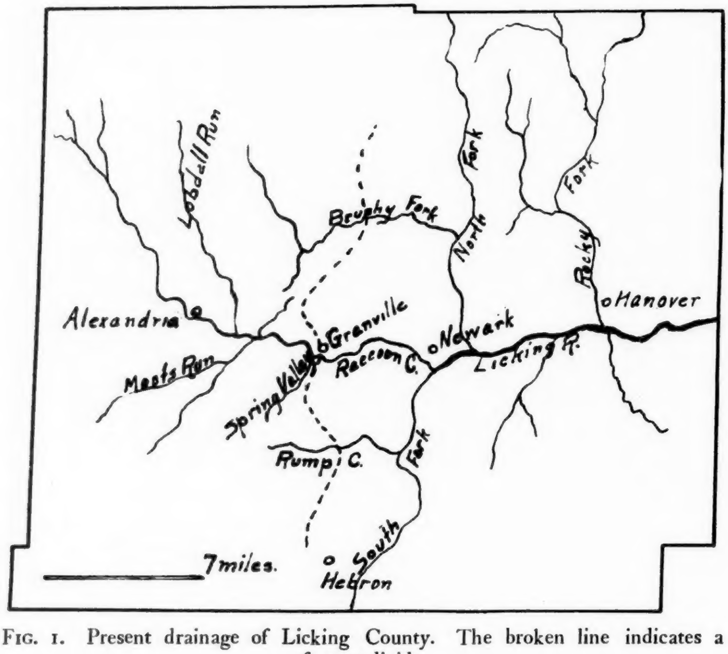

FIG. 1. Present drainage of Licking County. The broken line indicates a former divide.

with an enormous depth of glacial débris. On the Sinnett farm, about one-half mile east of Flower Pot hill, a drilling made in probably the middle of the valley discovered 274 feet of loose material overlying the rock floor. This added to the altitude of Flower Pot hill above the present valley bottom gives a total depth for the uncovered valley of over 325 feet. Subtracting the thickness of the unconsolidated material from the surface

altitude, the altitude above sea-level of the rock-bottom is here approximately 646 feet. The A. R. Wright well, located about five miles west, also in the valley bottom, has an altitude of 930 less 170, or 760 feet above sea level. The Colville well, three-fourths of a mile east of Alexandria and very close to the débris divide between the valleys of the Raccoon and Brushy Fork, has an altitude of 931 less 238 or 693 feet. While for the purpose of logical treatment it is desirable that all data should be

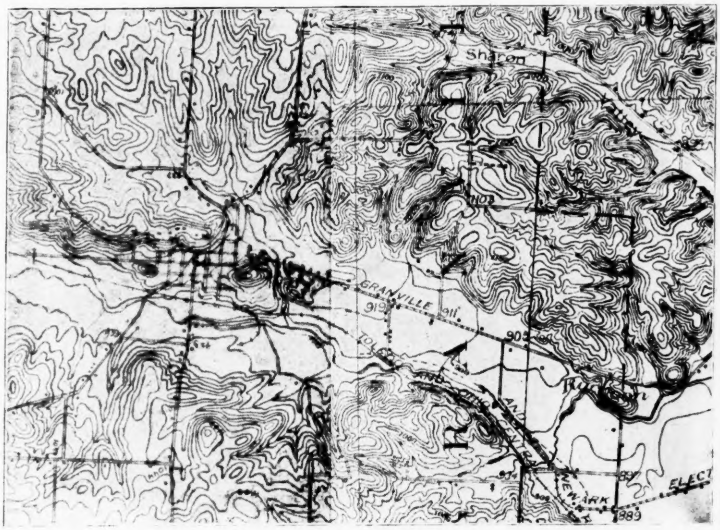

FIG. 2. Topography of the region about Granville, based on "advance copies" of the Newark and Granville sheets supplied by Mr. J. H. Jennings, Geographer, U. S. Geological Survey.

secured from corresponding points relative to the valley center, it is impossible to determine absolutely whether the data given conforms to this. Nevertheless it seems safe to conclude from all the drillings, including several in addition to those given above, that the altitude of the rock-bottom west of the Sinnett well gradually rises as it approaches Alexandria. The Colville drilling, though west of the Wright well, has a much lower rock bottom and probably lies near the center of the old Alexandria river.

The statements of drillers and managers indicate that most of the rock formations shown in the drillings are approximately uniform in thickness throughout the county; but they give varying statements for the "slate" (Berea[24] or Sunbury[25] Shale, probably including some Cuyahoga) found directly above the "Berea Sand," so-called by the drillers, and underlying the drift. Assuming that this "slate" when laid down conformed in this particular to the formations beneath, pre-Pleistocene erosion would be the natural cause of the present irregularity in thickness. By simple computation from records furnished, the Sinnett well is found to have a thickness of 184 feet of this uppermost formation, the A. R. Wright well 250 feet, and the Colville well 167 feet. The significance of this will be explained later.

All information obtained is uniform in supporting the theory that the strata dip east or southeast. One manager[26] stated that this dip equals thirty feet east per mile. Further computations from the three well records already quoted favor greater conservatism than this. The altitude of the upper surface of the "Berea Sand" (which it is assumed is uneroded and of uniform thickness in this area) is figured in the Sinnett well as 461 feet, in the Wright well 510 feet, and in the Colville well 526 feet. This dip, divided by the distance between the first and last, about 6 miles, gives an eastward slope of 19 feet per mile. The Black Hand Formation, the outcropping rock in this area, according to the measurements made by C. L. Herrick, and by Carney, shows a confirmatory dip. Herrick determined this dip near Granville to be 14 feet south and 18 feet east per mile. All the data[27] secured by him indicates the same general direction of dip for the other formations. Carney's work in Perry township shows a dip eastward of nearly 13 feet, and southward about 18 feet per mile.[28]

Tributaries. In the outlet portion of the Raccoon several tributaries break into the north wall. The largest of these occupied by Clear Run entering the Raccoon just east of Mount Parnassus, has extended its valley ramifications northwestward into the old divide. The principal tributary from the south has cut a deep

[24] E. Orton: *Geological Survey of Ohio*, vol. vi, p. 371, 1888.
[25] Chamberlin and Salisbury: *Geology*, vol. ii, p. 554, 1906.
[26] Fletcher S. Scott (private company), Newark, Ohio.
[27] *Bull. Sci. Lab., Denison Univ.*, vol. iii, pp. 24–5, 1888.
[28] *Ibid.*, vol. xiii, p. 120, 1906.

channelway almost parallel with the Raccoon into the first rock terrace, leaving it standing as a ridge merging into Flower Pot hill on the west. These streams generally head in circular-like valleys frequently wider than the lower portions, a character doubtless due to the fissile character of the lower rock in the valley walls.[29]

Of the tributaries to the wider portion of the Raccoon west of Granville, the one occupying an old wide valley to the south has been already mentioned. A small barbed tributary arising in the divide area is received from the north. Further west Lobdell Run from the north and Moots Run from the south are tributary.

In general the valleys tributary to the Raccoon show a contra-barbing to the east and west of the Granville col. Those to the east show a normal condition, i. e., the smaller angle made with the Raccoon points east. Those to the west show an abnormal tendency, i. e., the smaller angle points west or upstream relative to the present Raccoon. This contra-barbing is itself evidence of a drainage diversion: The tributaries to the lower end of the Raccoon conform to the normal tendency of tributaries in joining their trunk stream. When the abnormal is found, as west of the assumed former divide at Granville, the most satisfactory explanation is that at one time the present abnormal was normal, which in turn necessitates the hypothecation of an originally west flowing drainage at this point.

Incompetency of Glacial Explanation. The frequent obliterating effect of glaciers by masking the primitive topography with a mantle of drift makes absolute accuracy in the discussion of the preglacial histories of such areas practically impossible. Tight has favored glaciation as a cause of drainage changes[30] in central Ohio, although admitting without discussion the apparent preglacial origin of the lower end of the Raccoon and of the South Fork of the Licking. The glacial theory, if pertinent to this problem, presupposes an ice-mass coming from the west, ponding a body of water against the divide at Granville. This water would seek an outlet across this *S* divide toward Newark. The cutting of this divide could not be permitted, however, the entire length of Pleistocene time for completion, since the entire valley from

[29] F. Carney, *Ibid.*, p. 130.
[30] *Bull. Sci. Lab., Denison Univ.*, vol. viii, pt. ii, p. 37, 1894.

Alexandria to Newark has a deep filling of glacial débris, which as described by Tight[31] shows both Illinoian and Wisconsin characters. The presence of Illinoian drift east of the divide would indicate that if the col was cut glacially, it must have been completed during early Pleistocene times. "Spring Valley Stream,"[32] a tributary to the Raccoon, flowing laterally on the east wall of the "Old Valley" west of Flower Pot hill, could not have taken its original course[33] unless the divide had been previously removed. This again brings up the question of the competency of water deprived of its load to cut through such divides in the comparatively short time that may be granted.

To explain the capture at Granville the glacial theory would further require that the slope of the rock floor from Granville westward would be downward, and that this direction gave way to an eastward slope of débris because of the varying deposition of the latter. But the rock floor has been found by the drill records to slope eastward. This fact alone would seem sufficient to preclude any theory of capture due to glacial influences.

It may also be added that of all the cols noted in Licking county by the writer, none open toward the south. Many opportunities for the damming of water against east-west divides existed, while the direction of ice-movement further favored such phenomena. The persistent occurrence of these gaps opening toward the east does not seem in harmony with a glacial explanation.

Competency of Explanation by Diastrophism. That a divide formerly passed[1] north and south through Granville is obvious from physiographic evidence. If further evidence in addition to what has been given were needed, the Sinnett and Colville wells in their order westward may again be cited: In the first there is a thickness of the Berea formation of 184 feet, in the second 167 feet. The Sinnett well is obviously near the valley center and consequently marks the point of greatest erosion in this immediate locality. The Colville well in the wider valley westward shows a greater erosion by 17 feet. This difference alone is an indication of a former west flowing drainage, assuming that the Berea was originally of equal thickness at both places.

[31] *Bull.. Sci. Lab., Denison Univ.*, vol. viii, pt. ii, p. 37, 1894.
[32] E. R. Scheffel: *Loc. cit.*, pp. 158–160.
[33] *Ibid.*, p. 165.

As the slope of the rock bottom of the Raccoon valley from Alexandria towards Newark is now eastward, land-movement can be the only remaining explanation for the reversal of drainage west of the divide at Granville. The dipping of the strata eastward may be even suggestive of tilting in that direction. (It is admitted that the A. R. Wright well shows some discrepancy with all but the last of these explanations, but its harmonism with the latter suggests that the disharmonism is due to its probable situation on the old valley wall rather than on the valley bottom.)

Confirmatory evidence from other streams.—*Brushy Fork.* The northern débris boundary of the wide Raccoon valley to the west of Granville, as already mentioned, forms a divide between this valley and a similar one occupied by the headwaters of Brushy Fork. From this wide headwater valley Brushy Fork flows eastward toward a narrow rock-walled channel. This channel reaches its narrowest portion about a mile farther east and then very slowly widens until its junction with the valley of the North Fork of the Licking. Glacial débris *in situ* lying against the valley wall with water-laid material above has been noted. In its wide drift filled headwater portion and its narrow rock-walled outlet portion it is strikingly similar to the valley of the Raccoon. Throughout its length it is about parallel to the latter stream. In a north-south direction the narrowest portion of its valley would fall in approximate line with the narrowest portion of the valley of the Raccoon at Granville, the latter constriction representing the capture of a west flowing stream formerly tributary to the Alexandria river, which in turn was captured by the Brushy Fork.

Rump Creek. This stream is the next south of the Raccoon, flowing nearly parallel to it and emptying into the South Fork of the Licking river. Its valley shows a decided widening toward the west and narrowing toward the east similar to the condition noticed in the Raccoon and Brushy Fork valleys, with the greatest constriction in the same approximately north-south line. The length of the narrow portion is, however, much shorter than the other streams, this being due to the swinging southwest at this point of the South Fork of the Licking to which it is tributary, by which its eastward extension is cut off. No well data was obtainable in this area. The physiographic evidence makes it not unreasonable to suppose that glaciation may have been responsible for the capture, but the theory of land-movement is equally as reasonable.

The Licking Rivers. Both the North and South Forks of the Licking river occupy in their lower ends mature valleys well filled with débris. In the northern part of the county the North Fork turns sharply to the west, this portion formerly draining, according to Tight, directly to the Scioto System. At Newark the aggraded material reaches a maximum depth of 300 feet. This gives an altitude (above sea level) for the rock floor of about 500 feet.[34] Toward the southern part of the county near Hebron the valley, though continuing very wide, becomes drift-choked. Drillings, one showing a drift filling of 341 feet in Liberty township, Fairfield county, strongly support Tight's theory[35] that this valley was formerly continuous southwestward to the old Scioto drainage. It is noted west of Hebron also that the coarse sandstone capping the valley walls has been eroded much more than its equivalent the glass sand[36] formation, constituting the walls of the east-flowing Licking of which the South Fork is a branch. The inference is that the present most southerly portion of the South Fork must represent an older active drainage than that of the present east-flowing Licking. At the present time the South Fork of the Licking turns, just south of the county line, sharply north and west for its headwater drainage, becoming approximately parallel with the east-flowing streams before mentioned. The entire drainage of the North and South Forks and the Raccoon meets at Newark, passing eastward through a gorge-like valley narrower than the lower portion of any of these tributary valleys. This east-flowing stream, the Licking river, which receives nearly all the eastern drainage of the county, also, after a turn southeast, empties into the Muskingum river at Zanesville, and thence its waters pass southeastward to the Ohio river.

In the Licking System two points particularly may be noted:

1. The long tributary streams come from the north and west. These are, following to the left a circle including all the more important, the Rocky Fork, the North Fork of the Licking, the Raccoon, and in general direction the South Fork of the Licking. Such an arrangement would result, according to Campbell's theory, from a differential tilting toward the northwest or a differ-

[34] W. G. Tight: *Bull. Sci. Lab., Denison Univ.*, vol. viii, pt. ii, p. 36, 1894.

[35] *Ibid.*, p. 37.

[36] F. Carney and A. M. Brumback: *Ohio Naturalist*, vol. viii, pp. 357–60, 1908.

ential subsidence toward the southeast. "Tight has shown that the greater part of the Muskingum drainage system was formerly connected with the Scioto system by a broad valley leading from Dresden (a few miles above Zanesville) westward past Newark to the Licking reservoir, and thence into the Scioto basin near Circleville.[37] The present southward course past Zanesville is through a much narrower valley than the old line leading westward to the Scioto Basin, and the rock floor is markedly higher along the present course of the Muskingum than along the old course."[38] This old connecting drainage line Tight has named the "Newark river."[39] Besides carrying the old Muskingum drainage it received some of the streams now tributary to the Licking.

2. The east bank of the old Newark river so far as observed from Hanover to the Licking reservoir about 10 miles southward is abnormally steep considering the width of the valley. On the assumption that tilting has taken place this would be explained by an axis of uplift, approximately parallel to the valley, on the further side, or a corresponding depression on the near side. Under such conditions streams perpendicular to the axis also work headward and may finally capture the parallel streams.[40] The time required would depend on the vigor of the movement and the degree of intrenchment of the parallel stream sought for. With the case in point it is conceivable that an enormous period of time, representing a probably very slow movement must have been required for this diversion. While the old Muskingum was slowly reaching back through its tributaries to the old Newark valley, the drainage of the latter was in turn under cutting its left bank in an endeavor to escape eastward.

Conclusions. It appears from the evidence that formerly the drainage of the western part of Licking county passed directly to the valley now occupied by the Scioto System from the present headwater areas of the Brushy Fork, Raccoon creek and the North and South Forks of the Licking. The present lower portions of the same streams and also Rocky Fork (together, perhaps, with glacially obliterated streams from the south) drained into the same

[37] *Bull. Sci. Lab., Denison Univ.*, vol. viii, pt. ii, pp. 35–61, 1894.
[38] F. Leverett: *Monograph* xli, p. 155.
[39] U. S. Geological Survey, *Professional Paper* no. 13, plate i, 1903.
[40] M. R. Campbell: *Journal of Geology*, vol. iv, pp. 658–9, 1896.

old system through the former Newark river, having a general direction of west-southwest. Later all this drainage was diverted eastward through the present Licking valley.

No doubt has been expressed by any writer concerning the actual occurrence of the captures indicated. The general tendency, however, has been to refer them to glacial causes. Hints that differential movement may have been a factor have been given, but nothing has been adduced to support such a theory. The purpose of this paper has been to emphasize the possibility that this may have been the controlling factor even before glacial times, aided also by the stratigraphy which in at least part of the divide area permits rapid weathering. While arguments are available in favor of the glacial theory, yet in view of the fact that all the changes conform to the theoretical results following a simple differential movement of uplift or subsidence, it would seem that the latter factor should be given a more serious consideration than it has been accorded.

While the problem has been treated from a localized standpoint, a study of Tight's map[41] shows similar drainage changes over almost the whole of Ohio, including the drainage under discussion. Formerly this combined drainage passed northwest, now it passes southeast. May not the same cause have been operative in both instances causing the reversions; and may not the theory of differential movement be perhaps nearer the truth than the glacial?

PENEPLANATION

The hills of the western part of the county consist of rock of the Waverly Series. Tight in discussing the Muskingum area gives the Cretaceous as the probable period of base-leveling.[42] This time would also seem applicable to the Licking county area, though a later date is not improbable. If this supposition is correct then if these drainage changes were caused by differential movement this movement must have come between Cretaceous and Pleistocene times. Attempts have been made to correlate the rock formations of this area with those in the Allegheny Plateau

[41] *Professional Paper* no. 13, plate i.
[42] *Bull. Sci. Lab., Denison Univ.*, vol. viii, pt. ii, p. 55, 1894.

region. Differences of opinion have resulted,[43] but the areas have generally been accorded the same period (Cretaceous) of peneplanation.[44] Oscillations of the earth's surface have been evidenced in the Great Lakes area and in the Allegheny Plateau region.[45] The probability that the Ohio area under discussion has been genetically connected with some of these movements seems plausible.[46]

SUMMARY

1. This article has endeavored to throw some light on the subject of drainage changes near Granville, Ohio, first giving a brief of the general subject—drainage changes—in which the three principal causes are discussed: piracy, glaciation, and diastrophism.
2. The wide headwater and narrower outlet portions of the streams tributary to the North and South Forks of the Licking are evidence of a diversion to the east. The narrow outlet of the combined drainage through the Licking Narrows east of Newark further supports such a contention.
3. The commonly ascribed causes for such drainage changes in Ohio are not competent because: (*a*) So many similar phenomena are hardly consistent with a glacial cause. (*b*) Overflow streams would not be competent, in the times which may be granted, to do the enormous amount of cutting represented. (*c*) The eastward slope of the eroded rock floor, as illustrated in the Raccoon, strongly derogates against such a theory.
4. The reasons proving a diversion of drainage and those opposing a glacial explanation for such diversion, support, in general, the theory of diversion by tilting.
5. By differential land movement (probably in late Cretaceous times or possibly as late as the Pliocene) the drainage of Licking county has been diverted from the Old Scioto System west of Lick-

[43] C. L. Herrick: *American Geologist*, vol. iii, p. 95, 1889. C. L. Herrick: *Geol. Surv. of Ohio*, vol. vii, pp. 409, 501, 1893.

[44] W. M. Davis: *Bull. Geol. Soc. Am.*, vol. ii, p. 561, 1901. M. R. Campbell finds evidence of two peneplains in same area. See *Bull. Geol. Soc. Am.*, vol. xiv, pp. 277–96, 1903.

[45] F. Carney: *Am. Jour. of Sci.*, vol. xxiii, p. 326, 1907.

[46] F. Leverett: *Journal of Geology*, vol. iii, p. 763, 1895.

ing county to the southeast flowing Muskingum lying east of the same county.

6. If Point 5 is correct, then such an explanation rather than glacial may apply to most of the drainage changes of Ohio.

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June, 1908.

THE AGE OF THE LICKING NARROWS AT BLACK HAND, OHIO.[1]

KIRTLEY F. MATHER.

The Licking river is formed at Newark, Ohio, by the confluence of three streams, the North and South Forks, and Raccoon creek. Thence it flows almost due east and joins the Muskingum at Zanesville. Newark lies in the center of a broad open valley, partly filled with glacial drift, at the head of the Licking river. At Claylick, seven miles downstream from Newark, the Licking river leaves this broad old valley and continues eastward in a narrow channel which, a mile and a half farther on, becomes a gorge, cut 90 feet deep, in the Black Hand formation. The walls rise perpendicularly from the stream's edge and there is scarcely room for the railroad tracks on either side. The river winds through this gorge for a distance of two and a half miles, and at Toboso the valley widens out again to about half the width of the first valley at Newark.

The older and broader Newark valley continues from the vicinity of Claylick northeastward toward Dresden, but at Hanover is nearly filled with glacial drift. The rock topography of the region makes it apparent that in pre-glacial times this valley was occupied by a stream flowing southwestward, and tributary to the ancient Scioto. This stream has been named the Newark river, and it has already been pointed out that it must have been captured and diverted by the present east-flowing Licking.[2] The simplest hypothesis to account for this piracy would be that when the ice sheet, classified by Leverett[3] as Illinoian, entered this region it acted as a dam across the channel of the west-flowing

[1] This paper is the result of investigations undertaken, as a partial requirement for a Master's Degree, under the direction of Prof. Frank Carney of Denison University, and was read before the Ohio Academy of Science, November 28, 1908.

[2] Tight: *Bull. Sci. Lab., Denison Univ.*, vol. vii, part ii, p. 49, 1894.

Leverett: U. S. Geological Survey, *Monograph* xli, p. 155, 1902.

[3] *Ibid.*, p. 51.

stream causing its waters to back up into a lake, which, overflowing across the divide into a tributary to the Muskingum, would cut down the channel at the Licking Narrows.

Under this theory the present terraces in the valleys of the Licking and its tributaries would be deposits formed in the waters of this one large lake. Moreover, the drift which fills the Newark valley for a distance of three or four miles east of the Hanover dam would be in the nature of subaqueous outwash. It has already been shown[4] that this drift-filling is a deposit from a valley dependency of ice extending as far as the drift is found.

It is the purpose of this paper to show that a similar dependency stretched out down the Licking valley past Claylick, that no large lake occupied the valley at this point, and that the last capture and reversal of drainage in the Newark valley was accomplished before the invasion of the ice sheet.

The glaciation of the region. The ice of the Illinoian glacial stage entered this region from the west, and its frontal position was that of an irregular line drawn north and south through Claylick. At the time of the ice-advance the region was maturely dissected and the topography had a great influence on the work of the glacier.[5] In the valleys, tongues of ice extended for some distance in front of the main lobe while on the highlands the advance was retarded. Valley trains of sands and gravels stretch down the stream channels away from the ice-front.

It is quite difficult to map the exact limit of the ice as there are no topographic features, such as a terminal moraine, to help in the work, and because there was so much fluvio-glacial action which carried drift far beyond the edge of the ice.

The valley terraces. Between Claylick and the Narrows, the Licking river has four tributaries which join it from the south; these are designated *A*, *B*, *C* and *D* (fig. 1).[6] The first three of these streams flow in relatively broad valleys somewhat filled with drift. One of the most striking characteristics of these northward trending valleys is the persistent terrace which is found in each

[4] Carney: *Bull. Sci. Lab. Denison Univ.*, "The Glacial Dam at Hanover," vol. xiii, pp. 139–153, 1907.

[5] Leverett: *Loc. cit.*, p. 222.

[6] I am obligated to Mr. J. H. Jennings and to Mr. W. H. Herron, geographers of the U. S. Geological Survey, for an advance sketch of this portion of the Newark and Frazeysburg topographic sheets.

one. A detailed description of this feature in valley *A* will be typical of all three. Here the terrace is so persistent that it is impossible to climb from the stream bed to either divide without crossing it. It has a down stream slope of six or eight feet to the mile, but, as the gradient of the stream is several times as great, the top of the terrace is only fifteen feet above the bed of the brook at the south, while it is thirty-five feet above it at the northern end. The terrace is also slightly higher on the west than on the

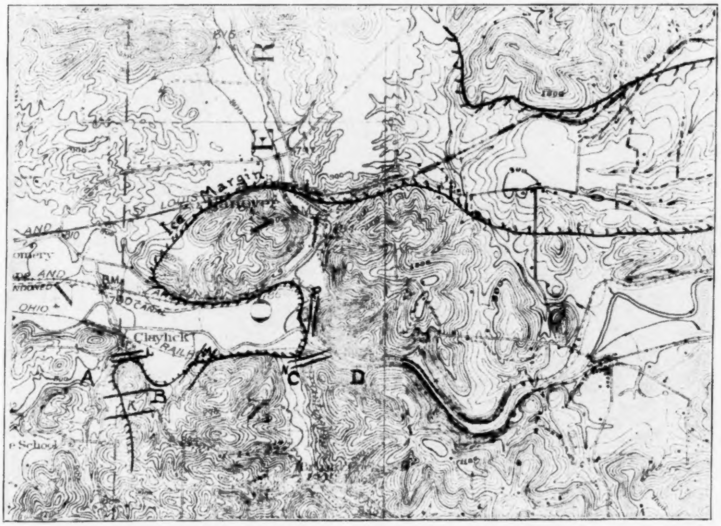

FIG. 1. Map of the Licking Narrows area. From the Newark and Frazeysburg Quadrangles, advance sheets, U. S. Geological Survey.

east; the combination of these two gradients is such that the lowest point in the terrace is just as high as the lowest point in the valley wall, at *K*.

The terrace is composed of fine sands, clays, and gravels, and varies in its composition in different places. At its northern end a gully cut in it reveals a section consisting of clay interbedded with fine loess-like sands. These sands are entirely free of gravels and have no distinct stratification or lamination. The clay beds are from two inches to nearly a foot in thickness and some of them

are quite persistent, though they are seldom horizontal. The upper foot or foot and a half of the terrace is here composed of waterworked gravels and small bowlders of foreign rock, evidently of fluvio-glacial origin.

A quarter of a mile farther up-stream, the terrace is thirty feet above the stream bed and here sands have been removed for molding purposes. The surface is covered by rubble and débris up to sixteen feet above the stream bed, but above this point a good section is exposed. At the base (fig. 2) is a fine gray sand with an intricate crossbedded and laminated structure. Two feet higher the sand becomes yellowish and clayey; the length of the ripples is nearly double the length of those below and the sand is finer and retains its shape when molded in the hand. The fine laminæ are accentuated by reddish, oxidized streaks, found only in this yellowish bed. This must mean that the oxidation took place during the deposition of the sand for only in that way could the lines of oxidation coincide with the lines of deposition. This deposit is five feet thick, and above it there is five feet of light yellow sand. The latter has occasional streaks of the gray sand found at the base of the section, but has nothing of the clayey character of the sands directly beneath it. This bed is about the same in texture as that at the base and has the same stratification and lamination. The three beds of sand grade into each other, are loess-like, and contain only an occasional small pebble and no shells. The remaining three feet of the terrace above them consists of gravels quite sharply separated from the sands beneath by a nearly horizontal plane, and quite evidently of glacial or fluvio-glacial origin.

Directly across the valley to the west of this section there is another place where sand has been carted away. The deposit here is similar to that in the upper and lower beds of the section just described. The cross-bedded structure is the same and its tendency to stand in vertical or even overhanging faces is also apparent. The upper surface of this deposit is ten to twelve feet above the surface of the terrace. It seems to fill the angle between the valley wall and the terrace surface and slopes upwards against the former. The whole deposit has the appearance of a fan spreading out from halfway up the valley wall and sloping down to the terrace level where it flattens out into the broad terrace.

These fine sands in the composition of the terraces in the three

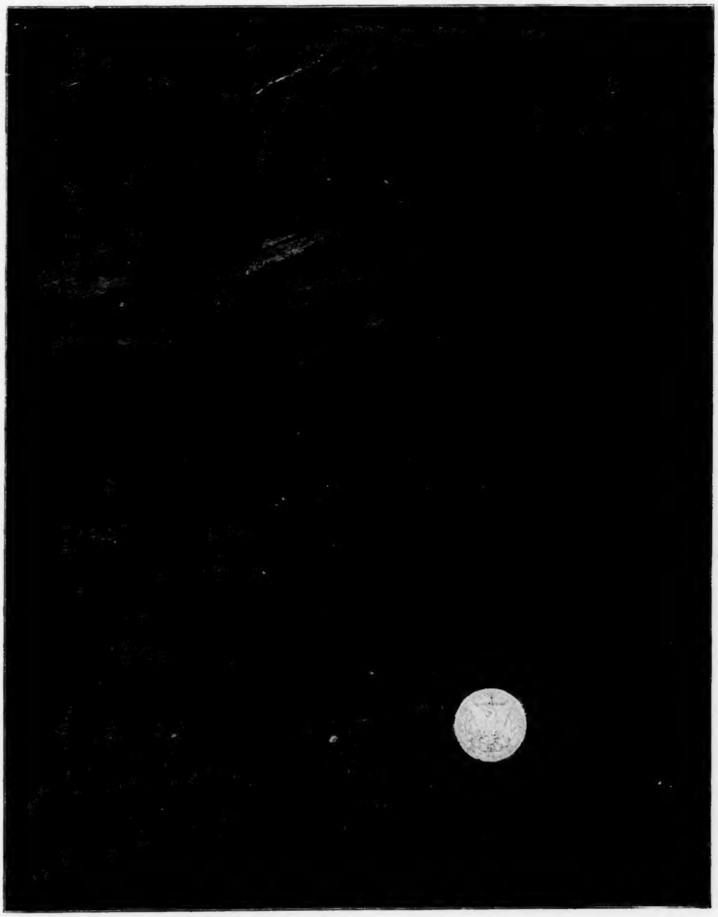

FIG. 2. Cross-bedded stratification of terrace in valley "A," near Claylick, Ohio

valleys are only found in a few localities and are not a general feature of the terrace structure. As a rule the terraces are made up of stratified and cross-bedded gravels, clays, and sands, alternating locally with areas of unstratified gravels. They present all the appearance of fluvio-glacial deposits made in a ponded or very sluggish stream containing unstable currents overloaded with material from the melting ice. This same conclusion is reached in a consideration of a similar deposit at Andover, Mass.[7] A photograph of the delta-plain material at that place presents an appearance very similar to that described in these terraces.

The terrace in valley *A* extends across the divide through the channel *K* into valley *B*. Here the same persistent terrace is found at a corresponding level. It sustains a similar relation to the brook as does the terrace in the first valley except that here there has been a little more erosion since its formation. This, however, is not antagonistic to the idea that the two terraces were formed at the same time in the same body of water because tributary *A* has been held up by a rock barrier near its confluence with the Licking while stream *B* everywhere flows on a till floor.

In valley *C* the same sort of a terrace, composed of similar materials, is found on both sides of the valley. At first inspection it appeared to be about the same elevation as the terraces in the other two valleys but when the topographical map of the region was obtained it became evident that here there was a discrepancy. The elevation of the terraces in valleys *A* and *B* is 830 feet while that in valley *C* is only 810 feet above sea level. The necessity of attributing these terraces to lacustrine deposition is here accentuated by the fact that at the southern end of the valley, where two smaller streams converge to form the tributary *C*, there are found delta-like deposits at the mouths of each of the small brooks. These delta-fans are the result of deposition, at the time that the lake occupied the valley, of the material brought to the lake by these two small streams.

It was pointed out that these terraces all contained assorted glacial drift, but in valley *D* no terrace nor glacial drift was discovered. This last valley, although younger and smaller than any of the three others, is of pre-glacial age. It is, also, broad enough to favor the formation and preservation of this same sort of terrace if glacial waters had been ponded in it.

[7] F. S. Mills: *American Geologist*, vol. xxxii, pp. 162–170, 1903.

From these facts it follows that the relation of the ice-sheet to the topography must have been such that the outflowing waters were ponded in valleys *A* and *B* at one level, in valley *C* at a different level, and were not ponded at all in valley *D*.

Old water channels. Three-fourths of a mile south of Claylick there is a broad sag (Channel *K*, fig. 1) connecting valleys *A* and *B* at the level of the terraces described above. The terrace in valley *A* is slightly higher than that in valley *B* and slopes gently eastward through this sag into the latter valley and is continuous

FIG. 3. Bench "L," near Claylick, Ohio.

with the terrace there. That this sag was the outlet of the lake in valley *A* at the time of the formation of the terrace system is evident.

The cemetery of the town of Claylick is situated on the bench marked *L* (fig. 1) and shown in the photograph (fig. 3). It must have been carved out of the hill slope by the overflow of the lake in valley *A*, which at some time evidently flowed across it. This course must have been taken by the stream after its diversion from the sag *K*, but before the complete withdrawal of the ice, whose front must have served as one side of the outflow channel at *L*. After the retreat of the ice sheet from that point the stream slipped off this bench and its course can be seen in a broad curve in the

foreground of the photograph; this curve marks the level where it paused for a time in the relatively rapid cutting of its channel in the unconsolidated glacial drift. A diagrammatic profile of this bench is shown in fig. 4.

Nearly a mile east of Claylick, at the point *M*, there is a much larger bench whose level coincides with that of the terrace in valley *B*, and is five feet lower in elevation than the sag *K*. The terrace can be traced around the valley, sloping gently from the sag to the bench. This bench was carved in the slope of the valley wall at this point, where there must have been a spur extending in a northwest direction into the valley. Almost in the center of

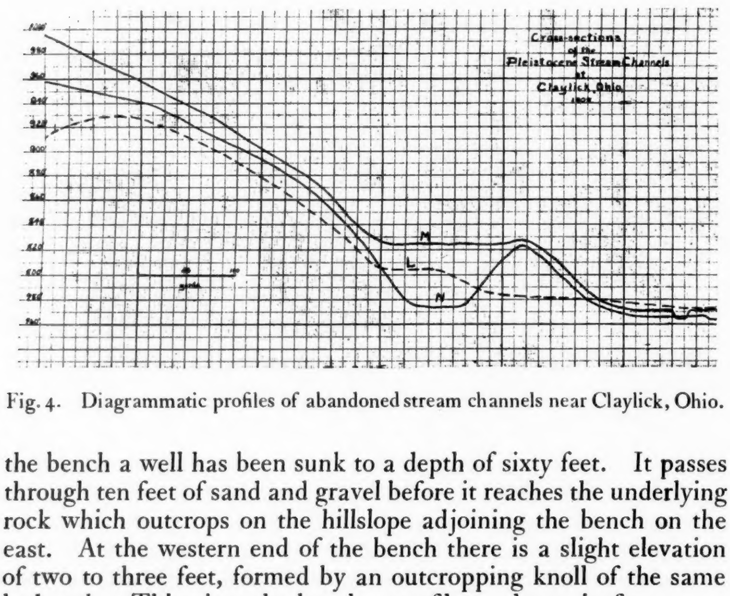

Fig. 4. Diagrammatic profiles of abandoned stream channels near Claylick, Ohio.

the bench a well has been sunk to a depth of sixty feet. It passes through ten feet of sand and gravel before it reaches the underlying rock which outcrops on the hillslope adjoining the bench on the east. At the western end of the bench there is a slight elevation of two to three feet, formed by an outcropping knoll of the same bed-rock. This gives the bench a profile as shown in fig. 4.

It is evident that at the time the terraces were formed the drainage from valley *B* flowed across this bench, producing its present shape. To do this the lateral stream from the glacier must have been held against the valley wall by the front of the ice.

Two miles east of Claylick, just at the entrance to the Licking Narrows, there are two more abandoned channels which were

carved by the glacial waters. (Channels *N* and *P*, fig. 1.) Channel *N* presents a profile as shown in the diagram, fig. 4. Its floor is continuous with the terrace on the adjacent valley slope and is covered with a thin deposit of sand and gravels, much waterworn, and underlain by the rock in place. That the tributary in valley *C* flowed through this channel at the time of the formation of the persistent terrace is quite evident. Since Pleistocene times it has reverted to its pre-glacial channel where it now flows on gravels ten feet below the level of the bed-rock in the old channel.

Channel *P*, across the Licking, shows similar structure and history; the origin of the two channels must have been the same. The only explanation that satisfactorily accounts for the carving out of these channels on the slopes of hills is that the ice-front abutted against them and served as one of the valley walls until the stream was well established in its new course.

The frontal limit of the ice sheet is, then, definitely located in these four places by the channels which resulted from its position. It is necessary, therefore, for us to postulate a valley dependency similar to, though smaller than, the one in the old Newark valley[8] extending, as shown in fig. 1, down the Licking valley until it was stopped by the steep slopes at the points *M*, *N* and *P*. Glacial bowlders have been found near the top of the hill just south of Claylick; this fact, combined with the small amount of cutting necessary to carve the bench at *L*, leads one to suppose that the latter was covered by the advance of the ice and was formed during a retreatal pause of the ice-front.

The capture of the Licking. The hypothesis has been published that "after the retreat of the ice the Licking Basin was closed and as the waters rose in Lake Licking they reached a low col in the divide a little south of Hanover. The position of this col is represented by the present Licking "Narrows.""[9] If this were the case terraces would be found in all four tributary valleys at the same elevation, for they would all be parts of the same lake. As stated above there is a marked discrepancy between the elevations of those in valleys *B* and *C*, while no terrace, or signs of a glacial lake, is found in valley *D*. The phenomena of the region do not, therefore, coincide with this hypothesis.

[8] Carney: *loc. cit.*, p. 149.
[9] Tight: *loc. cit.*, p. 49.

Moreover, the sag at *K*, the bench at *M*, and the channel at *N*. could not have been formed if the large valley had been occupied by a lake at that time. They must be the work of lateral drainage between the front of the ice and the adjacent hill-sides. This stream, and the rest of the water from the melting ice must have had an unobstructed passage out of the valley, which, as has been shown, was occupied by the valley dependency. This outlet could only have been through the present Licking Narrows. This necessitates the placing of the capture of the Newark river by the Licking in pre-glacial times.

Under this hypothesis the difficulties at once vanish and all the phenomena of the region are satisfactorily accounted for. The tongue of ice occupying the larger valley would have formed a dam across the mouths of the tributaries *A*, *B* and *C*, and would have caused a lake to form in each of them. The connection across the sag *K* would have made the body of water continuous in valleys *A* and *B* and accounts for the correspondence between the elevations of the terraces in them. In valley *C* the water would probably stand at a different level and this corresponds with the observations of the heights of the present terraces. In fact, this is the only hypothesis that can correspond with the phenomena and account for two different lakes at different levels in valleys *B* and *C*, and at the same time allow valley *D* to remain without fluvio-glacial deposits.

The waters from the lake in valley *A* at first overflowed across the sag *K* into valley *B*. Here the water level rose until it reached the lowest place of exit, where the ice front abutted the flank of the hill at *M*. The channel was gradually cut down until it formed the present bench. The stream of glacial waters flowing along the face of the cliff from tributary *B* to valley *C*, between it and the ice front, has left faint traces of the work of degradation in the slope of the profile. This stream, reinforced by the waters of the lake in tributary *C*, cut, at the point *N*, the same sort of a bench as now exists at *M*. The stream here was much stronger than at the latter place, and the channel was cut much deeper.

When the stream at *M* reached the level of the present bench a slight retreat of the ice occurred. This opened up the channel at *L* and separated the lake of valley *A* from that of valley *B*. The waters of the former then flowed across the bench at that point and carved it in the same manner as that already described

at *M*. This also accounts for the secondary level of terraces found in valley *A* at this elevation.

At the same time the lateral drainage from the ice was concentrated in a channel between the ice-front and the face of the steep hill due west of Claylick. This accounts for the steepening of the slope near the base of the hill as shown in fig. 5. The same slight retreat of the ice-front permitted the stream flowing over the bench at *M* to slip down off from it and occupy the natural channel

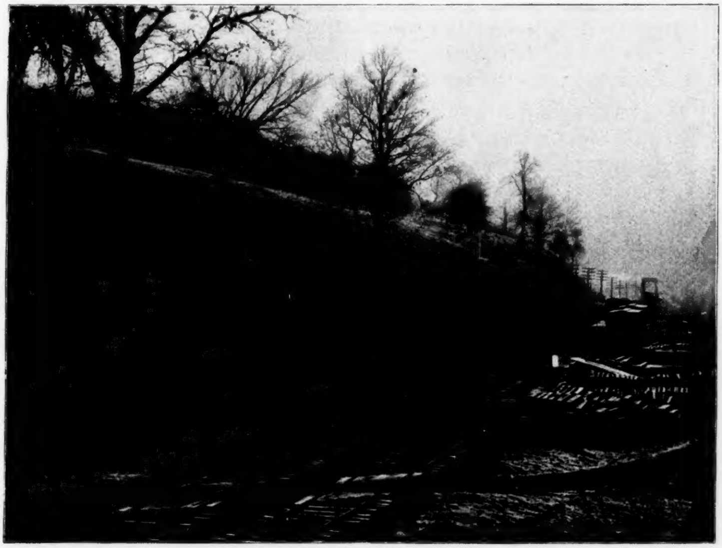

FIG. 5. View looking west from Claylick, Ohio. The steepened slope near the base is due to marginal glacial drainage.

between the glacier and the base of the slope; thus a similar steepening of the slope at this point was produced. The channel at *N*, before this oscillation, had become so firmly established that it retained its stream of water until the abnormal conditions due to the presence of the ice had been entirely dissipated. Then, a small stream working in the soft gravels, north of the outlier produced by *N*, captured and deflected the creek from its rock channel. This piracy can still be traced in detail in the former courses of the creek and its small branches.

Across the valley northeast of Claylick, the steepening of the base of the southern slope of the hills is indicative of similar glacial stream action between the ice-front and the valley wall. The village of Hanover is in a valley which, at the maximum extension of the ice, must have been occupied by a glacial lake, as shown by the terraces found here at an elevation of 800 feet. This lake was held up by the ice of two dependencies of the main sheet, one at either end of the valley. Its overflow and subsequent drainage conditions account for the channel at *P*, now occupied by the traction line and the old canal; this channel is similar in every way to the one at *N*, already described, and must have had a similar history.

An alternate hypothesis. It has been hypothecated that when the glacier advanced into the valley past Claylick the ice-front drainage would have had unusual erosive powers and might have channelled the divide area so rapidly that a lake condition did not exist long. It, however, is not conceivable that an ice-front stream would have been strong enough to cut a channel in the Black Hand formation a mile and a half long across a ninety foot divide without necessitating the ponding of the stream between the ice-front and the crest of the divide. The large amount of cutting necessary in the development of this channel, therefore, precludes the possibility of its having been made during the advance of the ice into the valley.

The cause of the capture and reversal. The capture of the west-flowing drainage by the east-flowing Licking immediately preceding the glaciation of this region—perhaps in the earliest stages of the Pleistocene period—is not discordant with our knowledge of conditions at that time. The close of the Pliocene is looked upon as a time of crustal movement, a critical period in the history of North America. Streams were turned from their courses in some places and nearly everywhere started on careers of increased activity.[10] A slight differential tilting would have caused the Muskingum and its tributaries to increase their valley cutting, and the reversal of drainage would have followed as the result of stream adjustment. The gorge of the Narrows is located at one side of a broad open valley having a lateral extension to the north of the crest of the gorge walls; this mature valley, at this point, was cut

[10] Chamberlin and Salisbury: *Geology*, vol. iii, p. 316, 1906.

down to the surface of the Black Hand formation, and it seems likely that its stream was flowing at this level when its action was increased by the tilting, probably near the close of the Pliocene, and the gorge started to develop in the bottom of the valley. As soon as this gorge had been cut back to where it could tap a tributary of the west-flowing drainage system, stream reversal commenced in the Scioto system. This was a slow process, and how far it had reached before the ice invasion is not known. The difficulties of working out these details are many, because the changes were greatly complicated by glaciation which soon followed the adjustments started by the differential tilting.

These discrepancies between the phenomena of the region and the hypothesis that the reversal of drainage was due to glaciation, together with the accordance of the phenomena with the theory of pre-glacial capture due to differential tilting, lead us to the conclusion that the Licking Narrows at Black Hand, Ohio, are of pre-glacial age.

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December, 1908